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FIRE ECOLOGY AND POPULATION BIOLOGY OF TWO TAIGA SHRUBS, LINGONBERRY, VACCINIUM VITIS-IDAEA AND ALPINE BLUEBERRY, VACCINIUM ULIGINOSUM

UNIVERSITY OF ALASKA M.S. 1981

FIRE ECOLOGY AND POPULATION BIOLOGY OF TWO TAIGA SHRUBS, LINGONBERRY, *VACCINIUM VITIS-IDAEA* AND ALPINE BLUEBERRY, *VACCINIUM ULIGINOSUM*

A

THESIS

Presented to the Faculty of the University of Alaska

in Partial Fulfillment of the Requirements

for the Degree of

MASTER OF SCIENCE

By

Bonnie Faith Friedman, B.S.

Fairbanks, Alaska

December 1981

FIRE ECOLOGY AND POPULATION BIOLOGY OF TWO TAIGA SHRUBS, LINGONBERRY, VACCINIUM VITIS-IDAEA AND ALPINE BLUEBERRY, VACCINIUM ULIGINOSUM

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ABSTRACT

Investigations of lingonberry, Vaccinium vitis-idaea and alpine blueberry, V. uliginosum were conducted one and two years after an experimental fire treatment in a black spruce ecosystem near Fairbanks, Alaska. The main objective of this study was to determine if a measure of fire severity can be used to predict Vaccinium response. A major effect of fire treatment was to increase variability in the depth and surface condition of the organic mat over relatively small areas. Residual organic mat depth was used to predict a significant portion of plant response. Fire treatment caused an overall increase in the number of blueberry stems and a decrease in lingonberry stems. Differences in the ability to return after fire were attributed to aspects of the autecology of the two species. Changes in shoot density were attributed to density dependent and density independent factors. Results from this study provided guidelines for Vaccinium management.

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INTRODUCTION

In interior Alaska, the black spruce (Picea mariana (Mill.) B.S.P) forest is the forest type which occurs most frequently and also has the highest fire frequency. Vaccinium vitis-idaea L. subsp. minus (Lodd.) Hult., lingonberry, and Vaccinium uliginosum L. subsp. alpinum (Bigel.) Hult., alpine blueberry, are two of the most common low shrubs in the black spruce forest type. The fruits of these species are important food components in the subsistence lifestyle as well as for various wildlife species.

Previous work had shown the importance of fire as a factor controlling the composition and productivity of the black spruce forest, however, little was known about the physical variables involved. Since these variables could not be reconstructed or estimated from wildfire studies, a series of prescribed experimental fires were planned to provide the setting for collecting measurements and observations before and after fires of varying intensity.

The Washington Creek fire effects study was undertaken as part of a larger study by the University of Alaska and the United States Forest Service titled The Structure and Function of a Black Spruce (Picea mariana (Mill.) B.S.P.) Forest in Relation to Other Fire Affected Taiga Ecosystems. The primary objectives of these experimental fires were to test the following hypotheses:

1) Fire, or other perturbations of the black spruce ecosystem which destroy the forest floor, including the moss layers, may result in increased mineral element circulation and vascular plant production and;

2) Since most understory woody plants in the taiga reproduce vegetatively from underground parts situated in the organic layer, early successional trends following a fire are dependent on the proportion of the layer consumed during the fire.

(Dyrness and Norum 1978).

The experimental fires were conducted during the summer of 1978 and resulted in an array of fire treatments. The study of shrub response, which is the subject of this thesis, was superimposed upon the overall fire effects study described above.

One of the main objectives of my study was to gain an understanding of the relationship between fire severity and the response of two taiga shrubs, lingonberry and alpine blueberry. In this study, the term "fire severity" was used to describe the effect of fire upon the forest floor in terms of the depth of the residual organic matter or the percent of the amount of organic material removed by fire. The term "fire intensity" as used here refers to the type or amount of heat created by the fire (Viereck and Schandelmeier 1980).

It was the intent of this study to determine if a measurement of fire severity may be used to predict Vaccinium response. In order to explore the relationship between fire severity and Vaccinium response, it was necessary to investigate certain aspects of Vaccinium ecology which may affect the ability of the shrubs to return after a fire. Some of these observations included information about the above and below ground distribution of plant parts as well as the seasonal variation in the ability of these species to respond to disturbance.

An additional objective of the study was to observe the population dynamics of Vaccinium in the early postfire community. An experimental fire situation made it possible to relate growth and change of Vaccinium populations to characteristics of the prefire community.

The observations of Vaccinium response were limited to the first two years following fire. The study was also limited to Vaccinium response to a particular set of burning treatments in the black spruce forest type.

LITERATURE REVIEW

EFFECTS OF FIRE ON VEGETATION

Fire is an integral feature of the northern environment (Black and Bliss 1978; Johnson and Rowe 1975; Kelsall, Telfer, Wright 1977; Slaughter, Barney, Hansen 1971; Wein 1978; Wright and Heinselman 1973). Due to the importance of the role of fire in Alaskan ecosystems, many aspects of fire effects have been studied and described. No attempt is made here to summarize the extensive literature on fire effects other than to point out that a recent and comprehensive publication summarizing fire effects on soils, watersheds, animals and vegetation in Alaska has been made by Viereck and Schandelmier (1980).

The recovery of boreal forest vegetation after fire has been the subject of numerous investigations (Foote 1976; Viereck and Dyrness 1979; Viereck et al 1979). Recovery sequences have been found to vary for different vegetation types and from region to region. It is agreed by most investigators that the rate of recovery and the composition of the postfire community varies according to the original cover and the type and intensity of burn since these factors determine the size and vigor of the residual flora (Archibold 1979). Consequently, many studies have focused upon the various factors responsible for determining the early successional sequences after fire. Such factors as preburn

conditions of the land, season of burn, seed supply, fire intensity, ash concentration, mineral nutrition, soil temperature and moisture, rainfall, humidity, soil and air temperature, animal populations and plant competition all determine the response of vegetation. (Ahlgren, 1960)

Viereck and Schandelmeir (1980) stated that in Alaska, one important factor determining successional sequence after fire is the amount of forest floor organic material removed by fire (or the fire severity). These authors felt that depth of burn is important especially in an ecosystem where much revegetation is from buried plant parts. A heavy burn that leaves little residual organic material will usually destroy or kill the underground parts of most, if not all, of the shrubs. In this kind of burn, species which establish from seed are favored. A light burn that kills only the above ground plant parts and chars the upper surface of the moss layer leaves the underground parts of the shrubs and many herbs intact. Revegetation in this case is primarily from sprouting of the underground plant parts. The authors indicated that the severity of a wildfire is difficult to determine after a few years and from their review of the literature concluded that when revegetation after fire is discussed, fire severity is not generally considered.

In Alaska and adjacent Canada, black spruce stands are widespread on wet, poorly drained sites and in the upland

and lowland sites underlain by permafrost. This vegetation type occurs over most of this area and is also the vegetation type with the highest fire frequency (Viereck 1973). As a result of investigations of burned stands in interior Alaska, Foote (1976) proposed a generalized successional scheme for the black spruce type consisting of six stages. These include: 1) newly burned (0 postburn years), 2) seedling-sucker stage (1-5 postburn years), 3) willow/shrub stage (6-25 postburn years), 4) dense hardwood, small diameter black spruce tree stage (26-50 postburn years), 5) dense black spruce/Pleurozium stage (51-100 postburn years), and 6) mature black spruce/feathermoss stage (greater than 100 postburn years). Depending on fire severity, Foote has found that stands may progress more or less rapidly from one stage to another during early postfire succession.

Viereck and Dyrness (1979) summarized the ecological effects of the Wickersham Dome fire near Fairbanks, Alaska. Fire effects described included the effects of burning upon the reduction of the organic matter of the forest floor. Early vegetation recovery was described and related to the fire intensity (heavily or lightly burned) three years after fire. Values of frequency of occurrence (%) and cover were determined for the vegetation. After the fire, the forest floor thickness in a heavily burned stand was 10.3 cm less than in an unburned control. In a lightly burned stand the difference was 5.7 cm.

Vegetation between heavily and lightly burned stands varied. Development of vegetation in the heavily burned stands was characterized by the slow development of shrubs and the herbaceous layer. The moss layer was slow to develop and the primary moss species was Ceratodon purpureus. The lightly burned stand developed in a different manner. After fire, nearly 40% of the ground cover was still alive and this residual vegetation developed rapidly.

Total cover of low shrubs in the heavily burned stand was less than 1% one year after fire while in the lightly burned stand cover was 15%. Low shrubs present in both heavily and lightly burned stands after fire were Vaccinum uliginosum, Ledum groenlandicum, Vaccinium vitis-idaea, Spirea beauverdiana and Ledum decumbens. Species which returned to lightly burned sites but not heavily burned sites were Oxycoccus microcarpus and Empetrum nigrum.

Total herb cover was 1% in heavily burned stands immediately after fire and 3% in lightly burned stands. The most common herb species present were Calamagrostis canadensis, Rubus chamaemorus and Equisetum sylvaticum.

Viereck et al (1979) reported the preliminary results of a series of experimental fires conducted in interior Alaska. In this study, the early recovery of vegetation was found to be closely related to fire severity. Fire severity was classified into five forest floor severity classes. These included:

1. Heavily burned - deep ash layer present, organic material in the soil consumed or nearly so to mineral soil.
2. Moderately burned - organic layer partially consumed, shallow ash layer present, parts of woody twigs remaining.
3. Lightly burned - plants charred but original form of mosses and twigs visible.
4. Scorched - mosses and other plants brown or yellow but species usually identifiable.
5. Unburned - plant parts green and unchanged.

Other investigations of post fire recovery in the black spruce forest have been reported by Black and Bliss (1978), Wein (1978) and others.

The potential for vegetative reproduction is an important factor for recovery after fire. Ahlgren (1960) found that the majority of species which came in vigorously within the first two years and maintained an important position during the first five year period following fire were of vegetative origin. This observation corresponded to Foote's (1976) "seedling-sucker stage" for the black spruce type in interior Alaska. Kershaw et al (1975) found that on recently burned surfaces the vegetation consisted almost entirely of new plants from the below ground systems of Ledum groenlandicum and V. uliginosum which were not destroyed by

fire. Racine (1979) found that in burned areas on the Seward Peninsula, Alaska, the cover and density of Ledum, V. uliginosum and V. vitis-idaea exceeded that of adjacent unburned areas. The origin of the shrubs was from buried stems which escaped burning from areas such as the tops and sides of tussocks. Revegetation was found to be much slower in areas where organic soils were largely removed.

Miller (1977) measured the vegetative response of blue huckleberry (Vaccinium globulare) to fire treatment in Montana and concluded that although postfire Vaccinium numbers were most closely related to the number of Vaccinium present before fire, the number of sprouts were found to be highly dependent upon heat exposure received by stems and rhizomes. Miller found a significant relationship between Vaccinium numbers and variables which affected rhizome survival. Some of these variables included prefire fuel loadings, fuel consumption, fire intensity, fuel, duff, soil moisture, soil temperature achieved during burning, and others.

The revegetation of an area after disturbance is principally from in situ growth of buried seed and/or underground plant parts or transport of disseminules to the area after disturbance (Moore and Wein 1977). Consequently an important part of the literature of fire effects is concerned with the ecology and differential survival of plants from the prefire community.

Moore and Wein (1977) have estimated the number of viable seeds present in different forest types in New Brunswick. They found that most viable seed was located in the upper 2 cm of the soil and that even a low intensity burn may destroy a large portion of the stored seed. The number of viable seeds in the soil decreased from 3400/m^2 in a deciduous-dominated forest to 370/m^2 in a spruce forest and to zero in a bog study site.

Johnson (1975) found no viable seeds in mature black spruce sites near treeline in the Northwest Territories. He indicated that buried seed populations generally decrease in a northward direction under unburned forests.

McLean (1968) related the relative fire resistance of forest species in British Columbia to root system characteristics and location. He found that susceptible species have fibrous root systems or rhizomes which grow above mineral soils. Moderately resistant species usually have below ground parts 5 cm below the mineral soil surface. Resistant species have below ground parts 5 to 13 cm below the mineral soil surface or have deep tap roots.

Archibold (1979) grew plants from soils from a burned area in Northern Saskatchewan and determined that of the plants which emerged, 87% originated from seed and 13% came from remnant roots or rhizomes. Lutz (1956) found that much of the shrub reproduction following fires in Alaska was

vegetative and that as a group, ericaceous shrubs and willows had a high capacity for vegetative regeneration through sprouts arising from stem bases and buried plant parts.

Flinn and Wein (1977) found in the forests of New Brunswick, that the depth of plant parts in the soil tended to be species specific. This information, combined with a knowledge of the sprouting ability of the underground plant organs was used to predict species response after fires of varying intensities. Plants with deeper subterranean parts were better protected from disturbance than species with shallow roots. Those species found at greater depths were the important species in the early stages of postfire succession. In other instances where parts of certain species were well protected, burning caused an increase in the relative abundance of such species while other more shallow growing species declined (Brayton and Woodwell 1966).

RESPONSE OF VACCINIUM TO FIRE

The response of Vaccinium angustifolium to fire has been investigated in order to increase commercial blueberry production by fire treatment (Hall 1955; Eaton and White 1960; Smith 1962).

Miller (1977) found variability in the postfire response of Vaccinium globulare due to prefire densities and fire treatment. The total number of V. globulare stems on

early season fires increased while on fall burned transects the number of stems decreased.

The response of V. uliginosum and V. vitis-idaea were included in the fire effects studies of Kershaw et al (1975), Racine (1979), Foote (1976), and Lutz (1956). Viereck and Dyrness (1979) compared the effect of burning upon the relative abundance of these two shrubs for three years after a burn in a black spruce stand. In lightly burned stands, V. uliginosum was found to have attained 5% cover as compared to less than 1% cover in a heavily burned stand. These values were far less than in unburned control stands where cover was 14%. V. vitis-idaea was 6% cover in lightly burned stands, less than 1% in heavily burned stands and 20% in unburned control stands.

Blueberry and lingonberry return to a site by resprouting from plant parts and seedlings of these species are not commonly found (Viereck and Schandelmier 1980; Lutz 1956; Racine 1979; Foote 1976). Uggla (1958) noted the rare occurrence of seedlings of V. vitis-idaea on severely burned soils where all subterranean plant parts have been destroyed by fire although the usual method by which this species would re-invade an area is by the spread of rhizomes.

Smith and Hilton (1971) compared the response of Vaccinium after fire and clipping treatment during different times of the growing season. Increased dry matter production

and increased percent cover resulted after spring and fall fire treatments while clipping at these times caused no increase in productivity. Summer clipping caused decreased productivity while summer fires showed no significant changes in shrub response. Differential response to clipping and burning have been attributed to increased nutrients and change in surface albedo caused by fire.

Miller (1978) performed a clipping treatment upon Vaccinium globulare during different times of the growing season to measure the seasonal variation in the ability of Vaccinium to produce shoots. Plants clipped after July 8 demonstrated irregular shoot development. Buds on plants clipped after August 4 did not develop.

ECOLOGICAL STUDIES OF VACCINIUM VITIS-IDAEA AND VACCINIUM ULIGINOSUM

Calmes and Zasada (in press) excavated clones of V. uliginosum in order to obtain information about the size and morphology of blueberry clones and the potential of this species for vegetative reproduction. Blueberry clones covered an area of 5 to 10 m^2. The number of above ground shoots per clone varied from 8-13. The ratio of above ground to below ground biomass for blueberry was found to be 1:9.7 ($\pm$ 2.0) in unburned areas and 1:3.1 ($\pm$ .5) in burned areas. The underground system of V. uliginosum occurred approximately 15-20 cm below the surface of the moss organic

mat. Clonal expansion for blueberry occurred by growth of above ground shoots which were eventually covered by organic matter accumulation. Rooting later occurred along the buried stems. Calmes and Zasada found no evidence of horizontally growing rhizomes for this species. Shoot production in blueberry was characterized by multiple-stemmed clumps which appeared to originate from the same bud site.

The area occupied by a lingonberry clone could not be determined from the literature although the total length of lingonberry rhizomes in individual clones ranged from .45-1.37 m on sites where rhzomes had decayed and parts of the clones had become separated, to 2.96-10.43 m long on sites where segementation of the clone did not occur (Smith 1962). In contrast to the low above ground to below ground biomass found for V. uliginosum by Calmes and Zasada, Tear (1972) found the above ground biomass to be almost equal to the below ground biomass in forest stands of lingonberry. The depth of lingonberry rhizomes was influenced by the depth of the organic soil horizons as Smith (1962) reported that rhizome depth varied from surface to 28 cm below surface. Uggla (1958) found rhizomes embedded under 2-3 cm of humus and Ritchie (1955) reported rhizomes to depths of 10-20 cm. All descriptions indicated that rhizomes were confined to the humus layer. The great majority of shoots arose at mid-rhizome locations (Smith 1962).

V. vitis-idaea was observed to spread vegetatively by rhizomes as compared to the "layering" process described for V. uliginosum (Calmes and Zasada in press). Rhizome growth was often rapid in open conditions. Due to this species' ability to "migrate" by this method of clonal expansion, lingonberry was found to recover from burns at faster rates than neighboring species in the British moors (Ritchie 1955). Tear (1972) noted that about five meters of new rhizomes per square meter were formed annually in a wild stand of undisturbed lingonberry. A comparison of the rate of vegetative spread for blueberry could not be found from the literature although the rate of spread would have to be equal to the amount of annual shoot growth and the rate of burial by moss of the decumbent stems.

The total number of shoots per lingonberry plant was found by Tear (1972) to be 3-4 in closed forest stands and 9-16 in open stands. Plant propagation experiments indicated that there was one adventitious bud per 1.5 cm of rhizome and that 90% of the rhizome segments tested by Fernqvist (1976) produced 1 to 2 shoots per cutting. Calmes and Zasada (in press) found more variable results for shoots formed from blueberry cuttings ($2.0 \pm .90$) to (10.9 ± 3.0) but results were not comparable to lingonberry cuttings since they subjected cuttings to different treatments.

POPULATION BIOLOGY OF PLANTS

Plant ecologists are increasingly examining plant populations on the basis of the dynamics of modular units, a concept espoused by E. Darwin in 1800 (White 1979). Harper and Bell (1979) described two kinds of organisms. The first are considered to be unitary organisms as exemplified by humans. The genotypes of such organisms specify a unitary morphology. In most higher plants, however, the zygote develops into a modular organism in which a basic structural unit is iterated. The modular unit in plants is the axillary bud and its associated leaf. Harper and Bell (1979) felt that there has been a strong tendency among botanists to identify what is only the unit of modular construction as the "individual" for clonal organisms. Sprouting and shoot production of Vaccinium has generally been viewed in the literature as the formation of new individuals. Rather than have production of shoots of Vaccinium thought of as reproduction of new individuals, Harper and Bell (1979) have regarded the production of new shoots as the iteration of a basic structural unit. Production of new shoots is the growth, not the reproduction of clonal organisms.

A whole set of demographic properties stems directly from modular patterns of growth. The main differences between organisms with modular growth from organisms with unitary growth is that 1) the parts of modular organisms have their own birth and death rates, and 2) the placement

of modular units determines the form of the organism. A direct consequence of this difference is that the populations of modular organisms need to be studied at two distinct levels: 1) the number of zygotes that are represented (genets), and 2) the number of modules developed from each zygote (in plants with clonal growth, these are ramets).

In this context, the effect of a fire upon Vaccinium may be interpreted as the removal of whole zygotes at one level of the population (when an entire Vaccinium clone is destroyed) and as the removal of a number of modules of particular zygotes at the second level of population structure (when a portion of above ground stems are removed, but the entire clone is not killed). The sprouting response of Vaccinium to fire, based upon this view of population biology, is the iteration of the modular unit, the new shoot or ramet from the remaining portions of the clone. Since seed reproduction does not generally occur soon after fire, changes in the population at the genet level are not included in early postfire Vaccinium response. In this study, it was not possible to examine the dynamics of Vaccinium at the genet level. The genetic relationship of the ramets within the various plot sizes used in this study was not known. Based upon the clone sizes reported in the literature, however, it is believed that ramets of more than one genet usually were present even at the smallest level of examination ($\frac{1}{2}m^2$).

STUDY AREA

PHYSIOGRAPHY AND GEOLOGY

The Washington Creek Fire Study and Training Area is located about 40 km northwest of Fairbanks, Alaska in the west half of section 12 and the NE quarter, section 13 T4NR2W, Fairbanks Meridian. The area is situated within the Yukon-Tanana Uplands physiographic province (Wahrhaftig 1965) in an area of relatively gentle relief with rounded ridges oriented in a northeast-southwest direction. The Washington Creek experimental fire site, located within the area, is situated on a ridgetop, between the drainage of Cushman Creek and Washington Creek, at an elevation of about 520 m (Fig. 1). The area slopes to the southeast into the Washington Creek drainage. Geologically, the site is characterized by mica schist bedrock of the Birch Creek Formation which has not been modified by glaciation (Viereck et al 1979).

CLIMATE

The Washington Creek area has a strongly continental climate with long, cold winters and short, warm summers. The annual temperature range is extreme, from -50° c to 35° c. At Fairbanks the average temperature in January is about -18° c and in July it is approximately 16° c. Annual precipitation averages about 35 cm, of which only about 30%

falls as snow. Precipitation during the summer averages about 4 to 5 cm per month and convective showers are common. (University of Alaska, 1979)

SOILS

Soils are formed on the mantle of loess which covers the bedrock. The soil at the experimental fire site is shallow Fairplay silt loam. The Fairplay series consists of moderately well to somewhat poorly drained silty soils. Typically, these soils have a thin organic mat over mottled dark, grayish brown, gravelly, silt loam that ranges from 50-100 cm in thickness over shattered schist. The proportion of gravel in these soils ranges from near zero to 35 percent by volume (Furbush and Schoenkorster 1974). Permafrost is not known to occur in the experimental fire site. However, if permafrost is present, it is well within the bedrock zone (Viereck and Dyrness 1979).

VEGETATION

Taxonomic nomenclature used for the vascular plants follows Hultén (1968). Nomenclature for the nonvascular plants are used as they appeared in Viereck and Dyrness (1979).

Vegetation of the Washington Creek experimental fire site consists of an unevenly spaced stand of black spruce, (Picea mariana (Mill.) B.S.P.) approximately 70 years old

with an understory of shrubs, herbs, mosses and lichens. Numbers of trees over 2.5 cm d.b.h. were found to range from 2,226 to 5,468 per hectare, with average diameters from 4.3 to 4.9 cm in a portion of the study area previously burned in 1976. The largest trees in this area were found to be in the 9-10 cm class and were 6.5 m in height. Paper birch, (Betula papyrifera Marsh.) alder, (Alnus crispa (Ait.) Pursh) aspen, (Populus tremuloides Michx.) and willow (Salix spp.) are scattered in the experimental area. Common shrubs are lingonberry, blueberry, and Labrador tea, (Ledum palustre L.). Lichens are conspicuous components of the ground cover and are primarily of the genera Cladonia and Peltigera. A nearly continuous moss cover made up mostly of the feather mosses, Hylocomium splendens and Pleurozium schreberi, is present (Viereck et al 1979).

METHODS

PREFIRE DATA COLLECTION

Firelines divided the experimental fire area into 7 units (Fig. 1). Each unit was approximately 1.6 ha and roughly square in shape. Five permanent $4m^2$ transects (8.0 x 0.5 m) were installed within each of the experimental fire units in May 1978 (Fig. 2) (One exception was Unit 1 which had 6 transects). Each transect was divided into eight contiguous $\frac{1}{2}m^2$ plots (1.0 x 0.5 m) from which the data were collected.

An inventory of the density of individual stems of both V. vitis-idaea and V. uliginosum was made for all plots. Stems which appeared to be separate from other stems above the moss level were each considered to be a separate plant (Fig 3a), even though stems may be joined just below the moss level (Fig. 3b). When stems were branched above the moss level (Fig. 3c), all stems were counted as one individual. Prefire data also included an estimate of cover for all vascular and nonvascular plant species. Three metal spikes were installed in the first, fifth and eighth plot in each transect. The spikes were placed within the plots so that the top of each spike was level with the prefire moss surface. A diagram of a transect with all measurement points appears in Fig. 2.

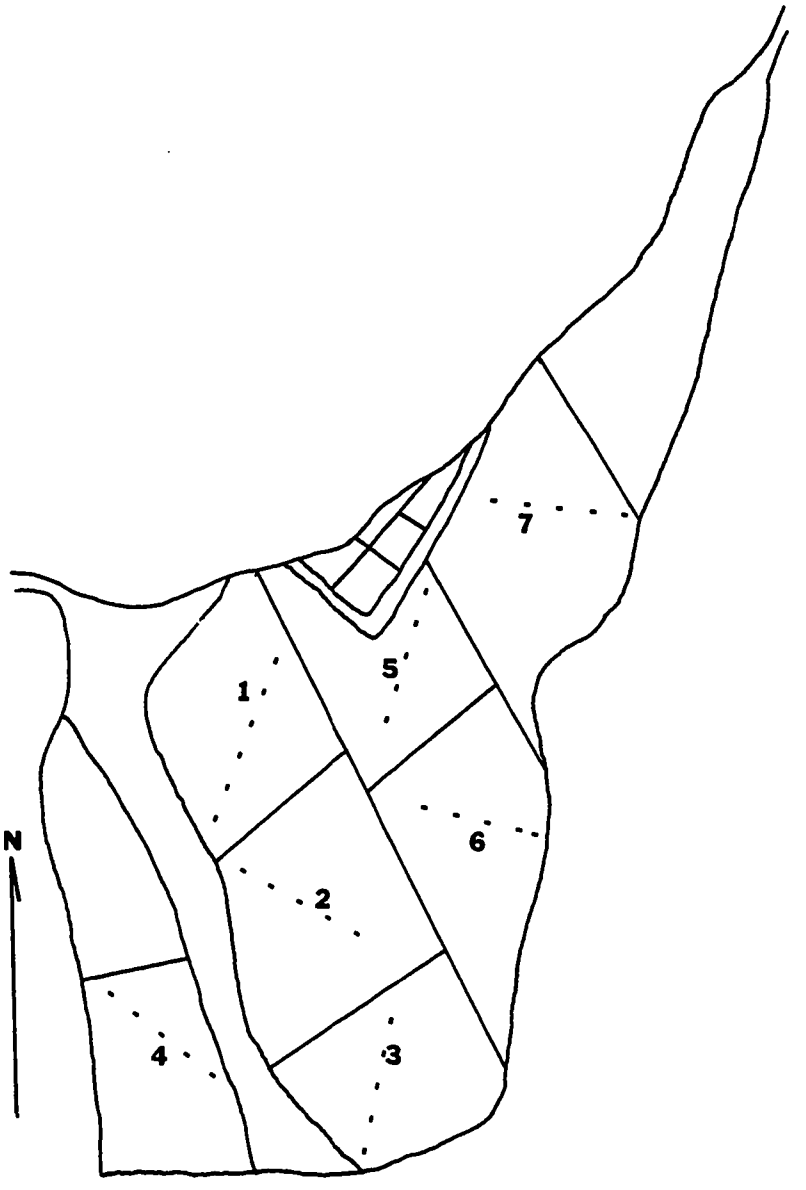


Fig. 1. Washington Creek experimental fire site. The location of the permanent transect within each of the 7 units is indicated by a small closed rectangle.

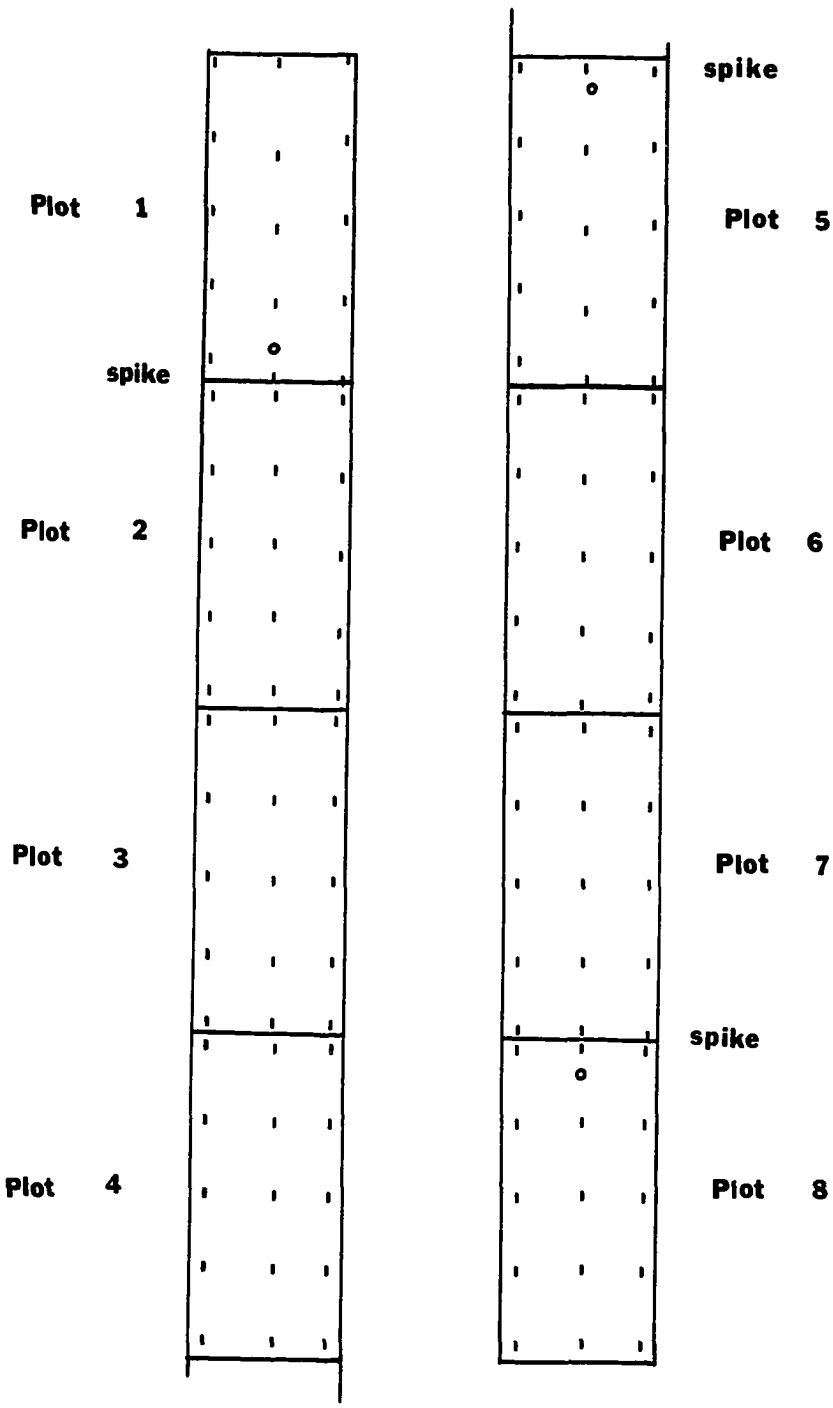


Fig. 2. Diagram of eight contiguous plots (0.5x0.1m) within a permanent transect. Closed rectangles in 3 rows throughout the transect indicate the location of residual organic measurements and open circles in plots 1, 5 and 8 indicate spike location.

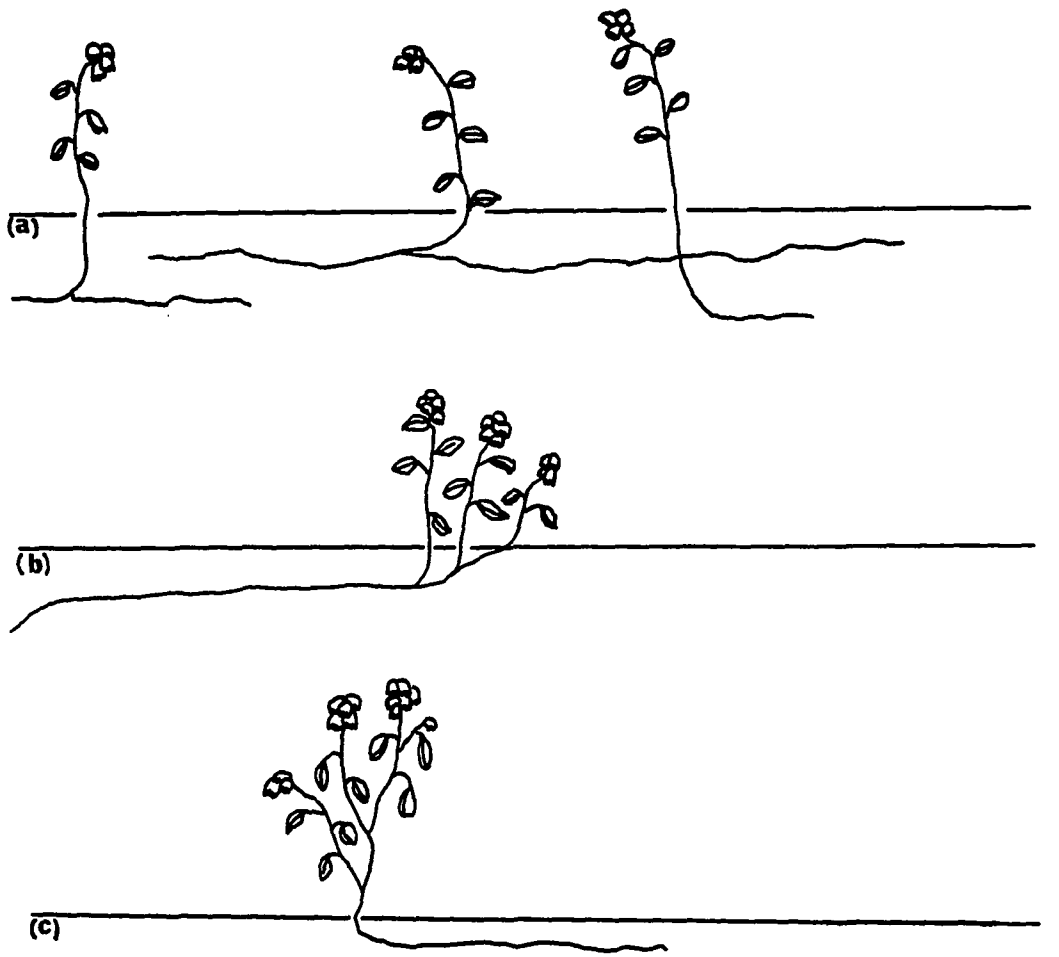


Fig. 3. Determination of Vaccinium density. Plants were considered to be separate individuals when stems appeared to be separate above moss level (a & b). A total of three individuals was tallied in a and b while only one individual was tallied in c.

FIRE TREATMENT

The experimental fires were planned for late spring or early summer 1978, although in late June and early July weather patterns around Fairbanks produced a "wet spring" condition which delayed the initiation of the experimental units until July 19 (Norum and Hill 1978). After that time, conditions remained suitable to continue burning until all units were completed on August 8. The following is a listing of dates of burn for the seven units:

July 19, 1978	Unit #1
July 20, 1978	Unit #5
July 31, 1978	Unit #7
August 1, 1978	Unit #2
August 4, 1978	Unit #3
August 4, 1978	Unit #6
August 8, 1978	Unit #4

Many variables were measured to aid in characterizing fire treatments. Some of these variables included continuous weather records such as temperature, relative humidity, rainfall, wind velocity and wind direction. Information on forest floor fuels, fuel moisture and surface mineral soils was collected just before ignition of the fire. During the fires, rate of spread of the fires and flame lengths attained were also measured. The overall effect of the experimental fires was to produce fire treatments of different intensities

which resulted in a continuum of fire severities. A detailed description of the different fire treatments and corresponding results have been summarized in "Washington Creek Fire Effects Study Summer 1978 Brief" by R. A. Norum and W. Hill (1978).

POSTFIRE DATA COLLECTION

1978

Immediately after the fires, the forest floor in all transects was characterized as to the severity of burning. The severity categories included: 1) heavily burned, 2) moderately burned, 3) lightly burned, 4) scorched, and 5) unburned (Viereck et al 1979) (A detailed description of the classes was included in the literature review) Residual organic layer depth was measured at 20 cm intervals in three rows throughout the length of the transect. Fifteen measurements were made for each plot and a total of 120 measurements were made for the transects (Fig. 2). The distance from the top of the spikes to the burned surface was measured to determine organic mat removal.

All plots were reinventoried for Vaccinium densities at the end of the growing season.

1979

In order to closely monitor shrub response, fire treated transects were revisited on a bimonthly basis throughout the

first field season after fire. Observations made for all $\frac{1}{2}m^2$ plots included counts of all new Vaccinium sprouts together with notes on their origin, growth and phenology. The definition of a shoot was discussed earlier (Fig. 3). Shoots were labeled by placing toothpicks beside them so that it was possible to determine survival and sprouting during each two week interval. Mortality was not recorded.

At the end of the field season, the total number of living shoots were counted for all plots. Shoot mortality of labeled Vaccinium was determined in all plots at this time. Percent cover for all species growing in the transects was also determined.

To better understand the nature of shrub response, it was necessary to gain information about the extent and location of the below ground systems of lingonberry and blueberry within the moss layer. The depths of the below ground systems of the two species were measured in undisturbed sites. Below ground systems of these species were excavated during mid-August in burned units in order to observe the process of postfire shoot development.

1980

Fire treated transects were revisited in May 1980, shortly after the area was free of snow. New Vaccinium shoots were tallied and overwinter shoot mortality was determined for previously labeled shoots in all $\frac{1}{2}m^2$ plots.

All evidence of browsing was tallied. The total number of living Vaccinium shoots were again counted in all $\frac{1}{2}m^2$ plots at the end of the 1980 growing season. Shoot mortality was recorded.

CLIPPING EXPERIMENTS

1978

Concurrent with the completion of the experimental fires was the initiation of a clipping treatment of six replications in an unburned area adjacent to the fire units. The plots, one square meter in area, were inventoried for the number of stems of blueberry and lingonberry present. All above ground stems were then clipped from all plots, except for one control plot. Twenty clipped "stumps" each of blueberry and lingonberry were labeled per plot to monitor shoot development.

1979

A second clipping experiment was conducted during the summer of 1979 to examine the seasonal variation of Vaccinium sprouting potential. At bimonthly intervals, four, one-m^2 plots were inventoried for the number of V. vitis-idaea and V. uliginosum stems present. Three of the plots were manually clipped and twenty "stumps" each of blueberry and lingonberry were labeled.

At the end of the 1979 growing season the total number

of shoots for all clipped and control plots was tallied both in the 1978 and 1979 clipping plots. The number of shoots which originated from the labeled Vaccinium "stumps" were counted separately.

1980

In September 1980, both the 1978 and 1979 clipping experiments were revisited. The total number of shoots in each m^2 plot as well as the total number of shoots from labeled stumps were tallied.

STATISTICAL ANALYSIS

Analysis of Postfire Data

Regression analysis was used to describe the functional relationship between postfire V. uliginosum and V. vitis-idaea density (Y) and fire severity (X). Because measurements were incomplete for Unit 4, it was not included in any of the analyses. Regression equations were generated from data collected at the end of the first and second growing season after fire. Vaccinium response was analyzed at two scales: density on the $\frac{1}{2}m^2$ plots and density on the $4m^2$ transects. Regressions were run using the raw data and transformed (log) data. Since some transects contained no Vaccinium sprouts, it was necessary to add a small value (+10) to all transects so that after log transformation, all transects could still be used in the regression analysis.

Two different measures of the independent variable, (X), which represented fire severity, were used in the analysis. The first was the depth of the residual organic matter, derived from 15 measurements per $\frac{1}{2}m^2$ or 120 measurements per $4m^2$ (Fig. 2). The second measure was the percentage of the total organic layer removed, as determined from the 3 spikes located on each transect (Fig. 2).

Since both X and Y were subject to error in this experiment, It would have been appropriate to use a Model II regression analysis (Sokal and Rohlf 1969). It was found, however, that portions of the data upon which both Model II and Model I simple linear regressions were performed yielded similar results and that programs to perform Model II multiple linear regression analysis were not readily available. Therefore, although all the assumptions were not met which would permit the use of Model I regression analysis, this method was used to obtain the regression coefficient, R^2 values and an analysis of variance F-test. All Model I regression analysis was performed with the use of a prepared program on the Hewlett Packard 9831 A computer.

Multiple linear regression analysis (Sokal and Rohlf 1969) was used to determine if the addition of a second independent variable, the number of V. vitis-idaea or V. uliginosum shoots present in the transects before burning, would result in more precise predictive equations. All

combinations of measures described for linear regression analysis (i.e., transformed and untransformed data, depth of organic layer remaining and percent organic layer removed, and $\frac{1}{2}m^2$ plot and $4m^2$ transect scales) were used with density data from both Vaccinium species for both years. An additional multiple linear regression trial was run for only those plots with an average organic layer depth of greater that 15.0 cm. The significance of the regression equations was determined by an analysis of variance F-test.

A comparison of R^2 values obtained from both the multiple and simple linear regressions was used to determine which combinations of variables produced the equations with the highest explained variance.

In order to determine if the relationship of postfire Vaccinium density to fire severity changed between 1979 and 1980, a "t-test" was used to test the mean R^2 values obtained for regressions with 1979 data with mean R^2 values from 1980 data.

Analysis of Clipping Experiments

The mean number of shoots was determined from clipping experiment plots one year after treatment. In order to determine if Vaccinium response varied from disturbance at different times of the growing season, the mean number of shoots growing on plots clipped before July 17 was compared to the mean number of shoots growing on plots clipped after

July 17. A "t-test" was used to determine if the two means were significantly different.

RESULTS AND DISCUSSION

GENERAL EFFECTS OF FIRE

The effects of the experimental fires in the black spruce forest were to create postfire conditions which were a tessellation of unburned, scorched, partially consumed and completely consumed organic material. These conditions were inlaid upon the vegetation mosaic resulting from previous fires.

The effects of fire treatment were never uniform throughout an area. Even where some sections of the post-fire landscape appeared to be composed of uniform expanses of blackened spruce poles and charred surfaces, closer examination revealed that enclaves remained where much of the organic mat was unburned. Likewise, in other sections where the appearance of the ground cover was generally scorched or unburned, there still existed some patches of severely burned ground where most or all the organic material was consumed.

Prefire vegetation

Prefire vegetation consisted of an unevenly spaced stand of approximately 70-year-old black spruce. The understory consisted of low shrubs and a nearly continuous cover of mosses and lichens. All percent cover values are reported in Table 1. The average value for the moss cover was 74%.

Table 1. Species cover values before fire treatment (1978).

Species	Percent cover followed by standard deviation Unit 1 Transect 1	2	3	4	5	6
Trees:						
Picea mariana	16(34)	35(23)	30(31)	27(34)	52(39)	19(25)
Populus tremuloides[1)]	0	0	0	0	0	0
Tall shrubs:						
Alnus crispa	0	0	0	0	0	0
Rosa acicularis	0	0	0	0	0	0
Rubus idaeus	0	0	0	0	0	0
Salix spp.	0	1(2)	0	0	0	0
Spirea beauverdiana	0	0	0	0	0	0
Low shrubs:						
Empetrum nigrum	4(6)	3(3)	7(3)	3(3)	2(2)	17(16)
Ledum palustre	3(5)	8(4)	6(5)	2(2)	5(8)	4(5)
Vaccinium vitis-idaea	13(15)	19(6)	19(8)	14(9)	20(14)	20(21)
Vaccinium uliginosum	14(10)	18(10)	17(6)	48(26)	7(10)	8(7)
Herbs:						
Calamagrostis canadensis	0	0	0	0	0	1
Cornus canadensis	1	1	1	1	1	4(10)
Corydalis sempervirens	0	0	0	0	0	0
Epilobium angustifolium	0	0	0	0	0	0
Geocaulon lividum	0	1	1	0	1(1)	1
Lycopodium spp.	5(9)	0	1(1)	1	1	1(3)
Non-vascular plants:						
Marchantia polymorpha	0	0	0	0	0	0
Mossess[2)]	34(31)	71(25)	92(3)	75(17)	24(19)	66(32)
Foliose lichens	9(11)	8(6)	6(5)	23(18)	3(2)	7(5)
Fruticose lichens	8(12)	6(7)	4(5)	2(2)	1(2)	11(10)
Average depth[3)] organic mat (cm) for unit			20.0			

[1)] *Populus tremuloides* were present in the units but not in experimental transects.
[2)] Mostly feather mosses (*Hylocomium sp.* and *Pleurozium sp.*).
[3)] C. T. Dyrness, personal communication.

Table 1. Continued

Species	Percent cover followed by standard deviation Unit 2 Transect 1	2	3	4	5
Trees:					
Picea mariana	15(14)	29(28)	45(31)	13(6)	57(43)
Populus tremuloides[1)]	0	0	0	0	0
Tall shrubs:					
Alnus crispa	1	0	2(4)	0	0
Rosa acicularis	0	0	0	0	0
Rubus idaeus	0	0	0	0	0
Salix spp.	0	7(18)	0	0	0
Spirea beauverdiana	0	0	0	3(5)	1(3)
Low shrubs:					
Empetrum nigrum	2(3)	2(3)	0	(2)2	1
Ledum palustre	0	1	0	1	1
Vaccinium vitis-idaea	10(6)	10(7)	10(8)	10(5)	9(5)
Vaccinium uliginosum	12(15)	16(10)	1	14(11)	1
Herbs:					
Calamagrostis canadensis	3(2)	7(8)	12(11)	7(2)	7(6)
Cornus canadensis	11(7)	2(2)	3(2)	2(1)	3(2)
Corydalis sempervirens	0	0	0	0	0
Epilobium angustifolium	0	0	0	0	0
Geocaulon lividum	1	1(1)	1	1	1
Lycopodium spp.	0	0	0	0	0
Non-vascular plants:					
Marchantia polymorpha	0	0	0	0	0
Mosses[2)]	92(2)	81(8)	86(11)	81(17)	93(8)
Foliose lichens	1	8(9)	1	17(19)	1(3)
Fruticose lichens	1	1	1	0	0
Average depth[3)] organic mat (cm) for unit			29.4		

Table 1. Continued

Species	Percent cover followed by standard deviation Unit 3 Transect 1	2	3	4	5
Trees:					
Picea mariana	37(37)	36(27)	34(35)	58(42)	63(11)
Populus tremuloides[1)]	0	0	0	0	0
Tall shrubs:					
Alnus crispa	11(18)	2(3)	6(11)	0	0
Rosa acicularis	0	0	0	0	0
Rubus idaeus	0	0	0	0	0
Salix spp.	0	0	9(17)	3(5)	0
Spirea beauverdiana	1	0	0	0	2(4)
Low shrubs:					
Empetrum nigrum	0	1(2)	1	2(3)	0
Ledum palustre	0	0	10(8)	1(2)	0
Vaccinium vitis-idaea	6(5)	21(11)	11(5)	17(7)	5(6)
Vaccinium uliginosum	17(15)	10(9)	19(21)	19(18)	0
Herbs:					
Calamagrostis canadensis	7(5)	3(6)	2(4)	3(4)	2(1)
Cornus canadensis	0	0	1(2)	1	5(3)
Corydalis sempervirens	0	0	0	0	0
Epilobium angustifolium	0	0	0	0	0
Geocaulon lividum	1	1	1(1)	1	2(3)
Lycopodium spp.	0	0	0	0	0
Non-vascular plants:					
Marchantia polymorpha	0	0	0	0	0
Mosses[2)]	78(15)	48(30)	75(25)	57(20)	92(6)
Foliose lichens	0	0	2(4)	24(24)	0
Fruticose lichens	1	3(4)	1	2(4)	0
Average depth[3)] organic mat (cm) for unit			27.5		

Table 1. Continued

Species	Percent cover followed by standard deviation Unit 5 Transect 1	2	3	4	5
Trees:					
Picea mariana	24(35)	34(40)	43(31)	41(27)	25(34)
Populus tremuloides[1)]	0	0	0	0	0
Tall shrubs:					
Alnus crispa	0	0	0	8(17)	0
Rosa acicularis	1	0	0	1	1(1)
Rubus idaeus	0	0	0	0	0
Salix spp.	3(7)	0	2(4)	3(7)	0
Spirea beauverdiana	0	0	0	1	1
Low shrubs:					
Empetrum nigrum	6(6)	3(3)	3(2)	0	2(2)
Ledum palustre	8(8)	3(3)	4(5)	2(2)	0
Vaccinium vitis-idaea	15(12)	6(3)	8(6)	27(23)	7(6)
Vaccinium uliginosum	18(11)	9(7)	5(6)	0	3(3)
Herbs:					
Calamagrostis canadensis	2(3)	3(2)	4(3)	2(2)	1(2)
Cornus canadensis	1	1	1	2(3)	1
Corydalis sempervirens	0	0	0	0	0
Epilobium angustifolium	0	0	0	0	0
Geocaulon lividum	1	1	2(2)	1(1)	1
Lycopodium spp.	1	1	0	2(2)	1
Non-vascular plants:					
Marchantia polymorpha	0	0	0	0	0
Mosses[2)]	70(17)	80(21)	72(21)	66(34)	51(27)
Foliose lichens	15(11)	5(10)	13(13)	13(23)	4(3)
Fruticose lichens	1	5(7)	2(4)	6(17)	7(6)
Average depth[3)] organic mat (cm) for unit			24.3		

Table 1 Continued

Species	Percent cover followed by standard deviation Unit 6 Transect 1	2	3	4	5
Trees:					
Picea mariana	57(25	43(31)	56(20)	40(24)	43(29)
Populus tremuloides[1)]	0	0	0	0	0
Tall shrubs:					
Alnus crispa	0	0	0	0	0
Rosa acicularis	0	1(2)	0	0	0
Rubus idaeus	0	0	0	0	0
Salix spp.	0	3(7)	0	6(11)	9(18)
Spirea beauverdiana	1(2)	0	0	0	0
Low shrubs:					
Empetrum nigrum	0	2(3)	0	1	0
Ledum palustre	4(3)	2(4)	2(2)	2(2)	3(6)
Vaccinium vitis-idaea	10(3)	9(4)	9(4)	10(5)	18(8)
Vaccinium uliginosum	5(5)	1(3)	6(9)	16(13)	1
Herbs:					
Calamagrostis canadensis	5(3)	14(16)	4(4)	3(2)	6(6)
Cornus canadensis	3(2)	3(2)	3(3)	3(2)	2(2)
Corydalis sempervirens	0	0	0	0	0
Epilobium angustifolium	0	0	0	0	0
Geocaulon lividum	1	0	1	1	1
Lycopodium spp.	0	1	0	0	0
Non-vascular plants:					
Marchantia polymorpha	0	0	0	0	0
Mosses[2)]	87(15)	76(16)	84(24)	88(18)	88(10)
Foliose lichens	6(13)	9(12)	1	3(6)	0
Fruticose lichens	1(1)	1(2)	0	0	0
Average depth[3)] organic mat (cm) for unit			30.9		

Table 1. Continued

Species	Percent cover followed by standard deviation Unit 7 Transect 1	2	3	4	5	All Transects
Trees:						
Picea mariana	46(31)	21(25)	41(35)	45(35)	48(36)	38(14)
Populus tremuloides[1)]	0	0	0	0	0	0
Tall shrubs:						
Alnus crispa	0	0	0	10(17)	7(11)	2(3)
Rosa acicularis	0	0	0	0	0	1
Rubus idaeus	0	0	0	0	0	0
Salix spp.	3(9)	0	5(14)	0	0	2(3)
Spirea beauverdiana	3(4)	0	0	0	0	1
Low shrubs:						
Empetrum nigrum	2(3)	4(3)	5(4)	0	0	2(3)
Ledum palustre	0	2(3)	0	1(1)	1	2(3)
Vaccinium vitis-idaea	15(8)	10(6)	12(7)	7(5)	5(5)	12(5)
Vaccinium uliginosum	1	19(9)	24(13)	7(10)	2(3)	11(10)
Herbs:						
Calamagrostis canadensis	2(2)	3(2)	1	1	2(2)	3(3)
Cornus canadensis	0	1	1	0	0	2(2)
Corydalis sempervirens	0	0	0	0	0	0
Epilobium angustifolium	0	0	0	0	0	0
Geocaulon lividum	1	1(1)	1	1	1	1
Lycopodium spp.	1	0	0	0	0	1
Non-vascular plants:						
Marchantia polymorpha	0	0	0	0	0	0
Mosses[2)]	73(29)	90(7)	83(12)	70(72)	79(17)	74(17)
Foliose lichens	18(15)	8(8)	15(9)	2(2)	5(8)	7(7)
Fruticose lichens	0	1	1	1	1	2(3)
Average depth[3)] organic mat (cm) for unit			24.6			25.2

This cover was primarily the feather mosses, Hylocomium splendens (Hedw.) B.S.G. and Pleurozium schreberi (Bird.) Mitt. The average value for spruce cover was 38%. This value was a combination of cover from the overstory trees as well as from spruce saplings in the understory. The distribution of spruce cover was clumped throughout the burn units. Spruce cover in the transects ranged from 63% to 13%.

Lichen cover was more prevalent in open parts of the stand and comprised a significant part of the prefire vegetation. Cover was 7% for foliose lichens which included Nephroma arcticum (l.) Wild and Petigera spp. The fruticose lichens, primarily Cladonia spp. made up 2% of the cover.

Of the ericaceous shrubs, V. vitis-idaea and V. uliginosum were the most prevalent with cover values of 12% and 11%, respectively. The values for lingonberry varied from high values of 26% to low values of 5%. It was observed that high values occurred in those plots associated with high spruce cover and low lingonberry values were associated with more open plots. Blueberry was more common in open areas and less often associated with high spruce cover. Preburn values of blueberries in the transects varied from 48 to less than 1%. Empetrum nigrum L. and Ledum groenlandicium L. Oeder had overall cover values of approximately 2%.

The cover value for Calamagrostis canadensis (Michx.) Beauv. was 3%. Grass cover was not homogenous over the transects since no grass occurred in some transects while in others, grass cover attained values as high as 14%.

Species in the prefire black spruce community which had cover values of less than 2% included the herbs Geocaulon lividum (Richards) Fern and Lycopodium complanatum L, and the shrubs, Alnus crispa (Ait.) Pursh, Rosa acicularis Lindl., Cornus canadensis L and Salix spp. Overstory trees in the experimental units included Betula papyrifera Marsh and Populus tremuloides Mich., but cover values for these species were not included in the transect.

Litter, a major component of the prefire transects, comprised a cover value of 18%. Litter was made up of fallen spruce branches as well as leaves of the shrubs and the deciduous overstory trees.

Effect of Fire upon Vegetation

Variation in the intensity of the fires resulted in three general conditions regarding the presense of various plant species in the postfire community. These were: 1) species absent before, but present after fire, 2) species eliminated by fire and 3) species present before and after fire treatment (Table 1 and Table 2).

Species newly present in the transects after fire were Rubus idaeus L., Corydalis sempervirens (L.) Pers., Marchantia

Table 2. Species cover values one growing season after fire treatment (1979).

Species	Percent cover followed by standard deviation Unit 1 Transect 1	2	3	4	5	6
Trees:						
Picea mariana[1]	-	-	-	-	-	-
Populus tremuloides	0	0	0	4(6)	0	0
Tall shrubs:						
Alnus crispa	0	0	0	0	0	0
Rosa acicularis	0	0	0	0	0	0
Rubus idaeus	0	0	0	0	0	0
Salix spp.	0	7(11)	0	0	0	4(9)
Spiraea beauverdiana	16(35)	0	1	6(9)	0	5(14)
Low shrubs:						
Empetrum nigrum	4(6)	1(4)	0	1	0	3(5)
Ledum palustre	3(5)	6(4)	6(8)	4(8)	1	4(6)
Vaccinium vitis-idaea	13(15)	5(3)	9(4)	13(10)	8(4)	16(9)
Vaccinium uliginosum	14(10)	23(17)	14(8)	6(9)	23(11)	17(18)
Herbs:						
Calamagrostis canadensis	1	1	1	0	0	1
Cornus canadensis	1	1(1)	1(2)	1(1)	0	1
Corydalis sempervirens	0	0	0	0	0	0
Epilobium angustifolium	5(9)	0	1	0	1	0
Geocaulon lividum	0	1	0	1(1)	0	2(1)
Lycopodium spp.	5(3)	0	1(1)	1	1	1(3)
Non-vascular plants:						
Marchantia polymorpha	0	0	0	0	0	0
Mosses[2]	14(31)	0	1	14(11)	1	42(42)
Foliose lichens	9(11)	1	1	1	1	7(5)
Fruticose lichens	8(12)	1	1	1	1	11(10)
Average depth of organic mat (cm)	17.5	17.5	17.6	17.8	14.4	15.8

[1] All *Picea mariana* trees were killed except in unburned portions of unit 1. In all other transects, *P. mariana* is present only as seedlings, 1 percent cover.

[2] Most common mosses in burned units are *Ceratadon sp.* and *Polytrichum sp.*

Table 2. Continued

Species	Percent cover followed by standard deviation Unit 2 Transect 1	2	3	4	5
Trees:					
Picea mariana[1)]	-	-	-	-	-
Populus tremuloides	0	0	0	0	0
Tall shrubs:	0	0	0	0	0
Alnus crispa	0	0	0	0	0
Rosa acicularis	0	0	0	3(3)	0
Rubus idaeus	0	0	0	0	0
Salix spp.	0	0	0	0	0
Spiraea beauverdiana	0	0	0	0	0
Low shrubs:					
Empetrum nigrum	0	0	0	0	0
Ledum palustre	0	0	0	0	0
Vaccinium vitis-idaea	0	0	1	1	1
Vaccinium uliginosum	0	1	0	3(5)	1
Herbs:					
Calamagrostis canadensis	2(3)	1	6(14)	4(4)	7(11)
Cornus canadensis	0	0	1	0	5(6)
Corydalis sempervirens	0	0	0	0	0
Epilobium angustifolium	44(27)	37(14)	38(16)	6(6)	16(14)
Geocaulon lividum	0	0	0	0	0
Lycopodium spp.	0	0	0	0	0
Non-vascular plants:					
Marchantia polymorpha	3(8)	0	2(6)	2(3)	3(5)
Mosses[2)]	34(19)	35(12)	32(20	11(13)	9(11)
Foliose lichens	0	0	0	0	0
Fruticose lichens	0	0	0	0	0
Average depth of organic mat (cm)	4.1	4.0	6.2	10.4	10.9

Table 2. Continued

Species	Percent cover followed by standard deviation Unit 3 Transect 1	2	3	4	5
Trees:					
Picea mariana[1)]	-	-	-	-	-
Populus tremuloides	0	0	0	0	0
Tall shrubs:					
Alnus crispa	0	0	0	0	0
Rosa acicularis	0	0	0	0	0
Rubus idaeus	0	0	0	0	1
Salix spp.	0	0	0	7(14)	0
Spiraea beauverdiana	0	0	0	0	0
Low shrubs:					
Empetrum nigrum	0	0	0	0	0
Ledum palustre	0	0	0	0	0
Vaccinium vitis-idaea	1	1	0	0	0
Vaccinium uliginosum	4(5)	1	0	1	0
Herbs:					
Calamagrostis canadensis	12(14)	1	0	1	1(2)
Cornus canadensis	0	0	8(15)	0	0
Corydalis sempervirens	0	0	0	0	0
Epilobium angustifolium	18(28)	13(16)	36(18)	11(10)	44(17)
Geocaulon lividum	0	0	0	0	0
Lycopodium spp.	0	0	0	0	0
Non-vascular plants:					
Marchantia polymorpha	0	0	0	0	0
Mosses[2)]	9(18)	31(26)	49(25)	21(14)	20(21)
Foliose lichens	0	0	0	0	0
Fruticose lichens	0	0	0	0	0
Average depth of organic mat (cm)	13.0	4.0	5.1	5.2	5.0

Table 2. Continued

Species	Percent cover followed by standard deviation Unit 5 Transect 1	2	3	4	5
Trees:					
Picea mariana[1)]	-	-	-	-	-
Populus tremuloides	0	0	0	0	0
Tall shrubs:					
Alnus crispa	0	0	0	0	0
Rosa acicularis	1	0	0	0	0
Rubus idaeus	0	0	0	0	0
Salix spp.	1	0	10(19)	1(4)	0
Spiraea beauverdiana	0	0	0	0	0
Low shrubs:					
Empetrum nigrum	0	0	0	0	0
Ledum palustre	3(5)	1	0	0	0
Vaccinium vitis-idaea	5(3)	2(2)	0	1	1(2)
Vaccinium uliginosum	9(9)	5(8)	0	1	2(4)
Herbs:					
Calamagrostis canadensis	1	4(5)	2(3)	2(4)	3(5)
Cornus canadensis	1(2)	2(2)	0	1	1
Corydalis sempervirens	0	0	0	0	1(2)
Epilobium angustifolium	0	21(5)	25(6)	23(4)	32(9)
Geocaulon lividum	0	0	0	0	0
Lycopodium spp.	0	0	0	0	0
Non-vascular plants:					
Marchantia polymorpha	0	5(14)	6(14)	4(11)	9(16)
Mosses[2)]	1	1	9(11)	23(20)	4(7)
Foliose lichens	0	0	0	0	0
Fruticose lichens	0	0	0	0	0
Average depth of organic mat (cm)	22.9	14.6	8.6	6.2	12.0

Table 2. Continued

Species	Percent cover followed by standard deviation Unit 6 Transect 1	2	3	4	5
Trees:					
Picea mariana[1)]	-	-	-	-	-
Populus tremuloides	0	0	0	0	0
Tall shrubs:					
Alnus crispa	0	0	0	0	0
Rosa acicularis	4(5)	0	0	0	0
Rubus idaeus	0	1	0	0	0
Salix spp.	0	0	0	4(11)	0
Spiraea beauverdiana	0	0	0	0	0
Low shrubs:					
Empetrum nigrum	0	0	0	0	0
Ledum palustre	0	0	1	0	0
Vaccinium vitis-idaea	0	1	1	1	0
Vaccinium uliginosum	0	1	0	1	0
Herbs:					
Calamagrostis canadensis	3(5)	11(15)	2(4)	2(4)	0
Cornus canadensis	1(4)	1	0	0	1(4)
Corydalis sempervirens	0	0	1(3)	0	0
Epilobium angustifolium	25(15)	9(9)	14(15)	15(12)	23(19)
Geocaulon lividum	0	0	0	0	0
Lycopodium spp.	0	0	0	0	0
Non-vascular plants:					
Marchantia polymorpha	0	0	0	0	0
Mosses[2)]	9(7)	11(16)	9(14)	4(7)	13(13)
Foliose lichens	0	0	0	0	0
Fruticose lichens	0	0	0	0	0
Average depth of organic mat (cm)	---	9.6	8.8	8.3	11.5

Table 2. Continued

Species	Percent cover followed by standard deviation: Unit 7, Transect 1	2	3	4	5	All Transects
Trees:						
Picea mariana[1)]	-	-	-	-	-	1
Populus tremuloides	0	0	0	0	0	1
Tall shrubs:						
Alnus crispa	0	0	0	0	0	0
Rosa acicularis	0	0	0	0	0	1
Rubus idaeus	0	0	0	0	0	1
Salix spp.	0	0	14(11)	0	0	1(2)
Spiraea beauverdiana	0	0	0	0	0	1
Low Shrubs:						
Empetrum nigrum	0	0	0	0	0	1
Ledum palustre	0	0	0	0	0	1
Vaccinium vitis-idaea	1	1	2(2)	1	2(2)	2(4)
Vaccinium uliginosum	0	2(4)	7(8)	1	0	4(7)
Herbs:						
Calamagrostis canadensis	1	2(3)	0	0	2(2)	2(3)
Cornus canadensis	0	0	0	0	0	1
Corydalis sempervirens	0	0	0	0	0	1
Epilobium angustifolium	7(7)	34(35)	19(30)	3(4)	16(22)	17(15)
Geocaulon lividum	0	0	0	0	0	1
Lycopodium spp.	0	0	0	0	0	1
Non-vascular plants:						
Marchantia polymorpha	1(2)	0	0	0	0	1(2)
Mosses[2)]	0	0	0	0	0	12(14)
Foliose lichens	0	0	0	0	0	1
Fruticose lichens	0	0	0	0	0	1
Average depth of organic mat (cm)	10.0	10.0	14.7	10.1	8.4	11.0

polymorpha and Epilobium angustifolium L. The cover values for Rubus, Corydalis and Marchantia were 1% or less. The most prominent member of the postfire community was Epilobium which had an average cover value of 17%. Mosses, which included Ceratodon, Polytrichum and others attained an average cover value of 12% by the end of 1979. These new species were observed to invade areas with little or no residual organic mat. The origin of these species has been observed to be by seed or spore as opposed to vegetative means (Viereck and Dyrness 1979; Clautice 1974).

The greatest reduction in plant cover occurred for the feather mosses and lichens which were eliminated from all transects except those in Unit 1 which contained unburned portions. Black spruce trees were killed in all transects, but the species returned as seedlings one year later to some plots. Total cover for the spruce seedlings was always less than 1%. Other species which were observed one year after fire, but were eliminated in all but the unburned portions of the transects immediately after the fires were Empetrum, Geocaulon and Spirea (Table 2).

Species which were present in the prefire community and returned to treated transects one year after fire generally were decreased in cover. These species were the various shrubs and Calamagrostis. V. uliginosum decreased from 11 to 4% and V. vitis-idaea decreased from 12 to 2%. The cover of

Ledum changed from 2 to less than 1%. Other shrubs which decreased in cover were Rosa, Salix and Cornus. Calamagrostis decreased slightly in cover from 3 to 2%. Aspen returned to the community from suckers after the overstory trees had died. Total cover in the transects was less than 1%, but in other areas of the units, aspen suckers comprised an important component of the postfire community. As in the prefire community, the two species of Vaccinium still occurred in the highest proportions of all shrubs. Revegetation of most of the shrub species is believed to have occurred from below ground parts of these plants which survived the fires. (Viereck and Dyrness 1979).

Although total cover of the preburn vegetation (both vascular and non-vascular plants) was almost always 100% (Table 1), postburn vegetation seldom approached this value (Table 2). In transects characterized by a high proportion of fireweed, liverworts and mosses, total plant cover ranged from 50 - 60% with 40 - 50% bare mineral surface. In transects with resprouted species such as shrubs and grasses, total plant cover was usually about 20 - 30% with 70 - 80% charred moss cover.

Litter, a large component of the total cover in the transects before fire, was mostly consumed. However, following the fire, relatively dense accumulations of litter occurred quickly as the dead spruce needles fell to the surface.

Species present and percent cover were similar to results from other studies of early successional stages following fire in the black spruce type. (Foote 1976; Viereck and Dyrness 1979; Viereck et al 1979).

Effects of Fire Upon the Forest Floor

A major effect of fire treatment was to alter the depth and surface condition of the organic mat (Fig 4). Fire severity varied greatly over relatively small areas. Depths of the residual organic mat indicated that within a one meter distance the fire had consumed all but 2 cm of the organic mat in one place while leaving 26 cm intact in another. This difference indicated insignificant to total consumption of the organic layer across a relatively small area.

In some portions of the transect, all fire severity classes were represented within an area of less than one square meter. Differences in fire severity created a continuum of survival probabilities for plant propagules.

The vertical consumption of the organic mat may be used to explain survival of particular parts of a clone since the more shallow parts would be killed in some areas while the more protected parts would survive. Since the location of below ground propagules is generally species specific within the organic mat, (Calmes and Zasada in press; Flinn and Wein 1977) the vertical scale of consumption may explain survival

om 19.5 cm							
residual 14 cm	13L	14L	11L	20L	24S	27S	
	13L	10L	16L	16L	21L	24S	
Plot 1	5L	17L	11L	15L	14S	24L	Plot 5
	7L	7L	10L	19S	24S	18L	
	16L	17L	3L	24S	16S	16L	5 om: 26.5 cm residual 24 cm
	15L	14L	18S	26S	19S	19L	
	16L	18S	13L	23S	22S	26S	
Plot 2	17L	14L	15L	24S	26S	15L	Plot 6
	12L	18L	13L	16L	18L	20L	
	18L	14L	13L	7M	7M	15M	
	17L	13L	20L	2H	10M	15M	
	22L	13L	19L	2H	14M	11M	
Plot 3	16L	18L	16L	2H	5M	16M	Plot 7
	18L	18L	22L	10M	2H	10M	
	25S	26S	19L	2H	2H	2H	7 om: 29 cm residual 2 cm
	30S	21L	20L	2H	2H	2H	
	25L	28L	18L	2H	2H	2H	
Plot 4	20L	28S	17S	2H	2H	1H	Plot 8
	15L	24S	16L	1H	1H	1H	
	20L	24S	20S	1H	1H	1H	

Burn severity categories
- S = Scorched
- L = Light
- M = Moderate
- H = Hot

Fig. 4. Burn severity category and depth of residual organic matter (cm). All 4 classes appear in lower half of plot 6 and top half of plot 7.

of a particular species and elimination of others. The horizontal fire severity may define the potential for re-vegetation by a clone of a species. Since the entire range of fire severity may occur within one square meter and since the area occupied by clones of several common shrub species have been shown to be much larger than one square meter (Calmes & Zasada in press), portions of a clone may be unharmed even when other portions are killed.

Average preburn depth of the organic layer within all experimental units was 25.2 cm[1)]. Postburn depths ranged from 1.1 to 28.5 in the $\frac{1}{2}m^2$ plots (Appendix A). The average postburn depth was 11.0 cm for all plots.

RESPONSE OF V. ULIGINOSUM AND V. VITIS-IDAEA TO FIRES OF DIFFERENT SEVERITY

General Response of V. uliginosum and V. vitis-idaea

Fire treatment caused an overall increase in the average number of V. uliginosum stems while an overall decrease occurred for V. vitis-idaea (Table 3). One year after fire treatment, the number of blueberry shoots increased 145% while lingonberry shoots decreased to 25% of their original number. Two years after fire, blueberry shoots were 110% of their preburn density and lingonberries 23% preburn density. The variation in stem density increased after fire treatment.

[1)]Personal communication. (C. T. Dyrness, USDA Forest Service, Institute of Northern Forestry, Fairbanks, Alaska)

Table 3. Changes in the average number of Vaccinum shoots for all transects.

Species	Year	Mean Number of Shoots	Variance	% of Preburn Value
Vaccinium uliginosum	1978	13.1	156.7	100
	1979	19.2	1117.2	145
	1980	14.5	705.3	110
Vaccinium vitis-idaea	1978	100.0	1408.5	100
	1979	24.3	1968.4	25
	1980	22.6	1701.6	23

The parent who leaves and later reclaims the child at the ticket booth of the roller coaster ride would have experienced as much of the child's adventure as the ecologist who tries to understand changes in plant density by observing average densities for all plots. The average values tend to smooth over the natural fluctuations in plant populations. Figs. 5 and 6 illustrate the range of response to fire treatment on $\frac{1}{2}m^2$ plots over a transect. Preburn densities (Figs. 5a and 6a) illustrate the widespread trend that the average number of lingonberry stems outnumbered blueberry stems. In this transect, a sharp decrease occurred in the number of stems of both species after fire. On one plot V. vitis-idaea declined from 152 to 0. Only one $\frac{1}{2}m^2$ plot on the entire transect contained lingonberry shoots by the end of 1979. No shoots of V. uliginosum appeared in 6 of the 8 plots although it is interesting to note that in plot 3, where shoots did return, more shoots were present than before fire.

In other transects, the reduction in lingonberry numbers was not as dramatic (Fig. 6). In plot 4, where there were 59 shoots before fire, there were 25 shoots (Fig. 6b) after one growing season. The response of blueberry in this transect also differs from the previously described transect by exhibiting a large increase in shoot numbers. The density of blueberry in plot 4 (Fig. 6b) increased sixfold one year after fire treatment.

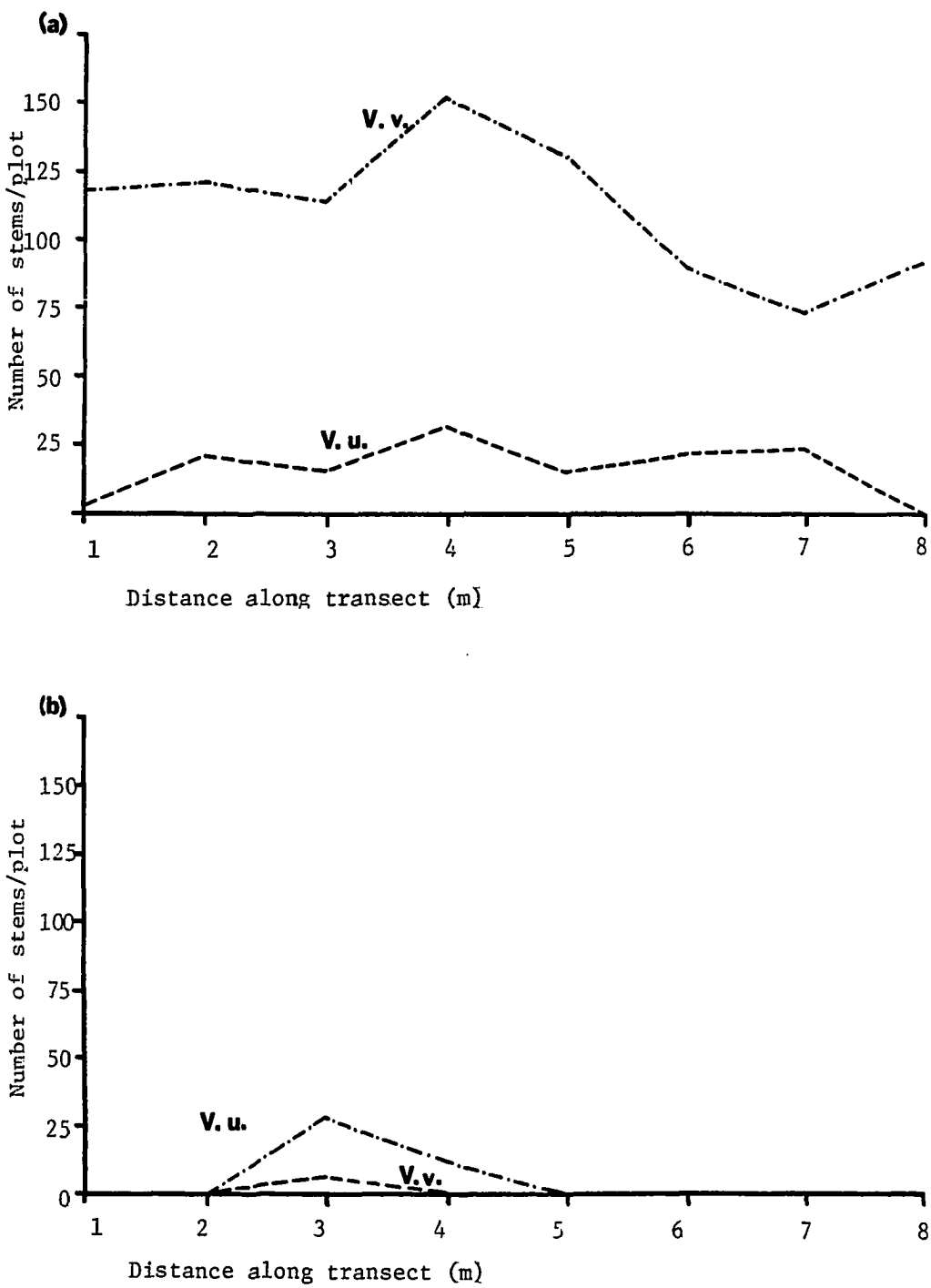


Fig. 5. Vaccinium response to severe fire treatment one year after fire. Comparison of densities of V. vitis-idaea (v_1v_2) and V. uliginosum (v.u.) before (a), and one year after burning (b).

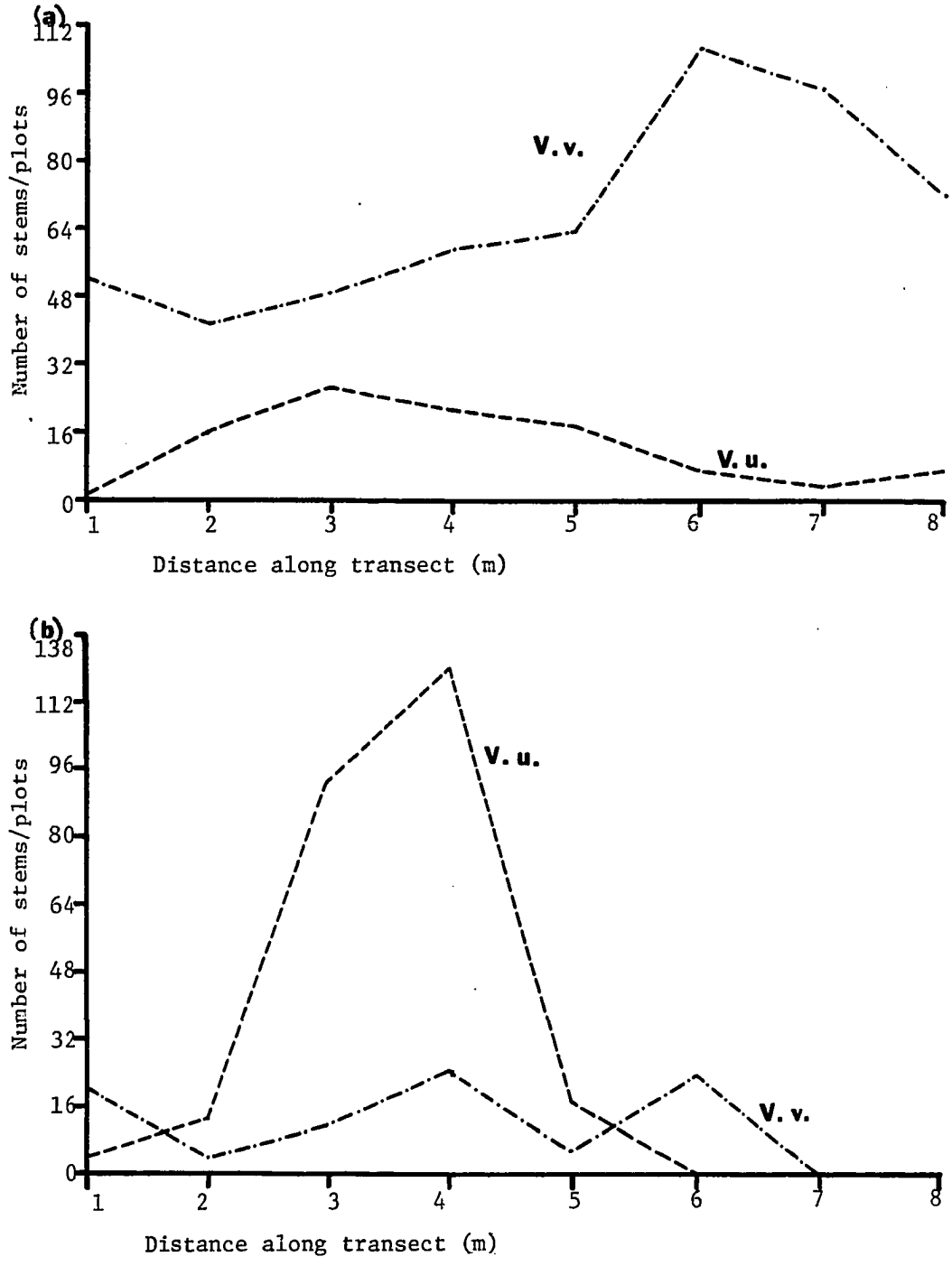


Fig. 6. Vaccinium response to light fire treatment one year after fire. Comparison of densities of V. vitis-idaea (V.v.) and V. uliginsum (V.u.) before (a) and one year after burning (b).

Figs. 5 and 6 exemplify the two most commonly observed responses. More than one half of the $\frac{1}{2}m^2$ plots (59%) had no shoots returning after the first year (Appendix A). The remainder of the plots had a positive shrub response for V. uliginosum density and a negative shrub response for V. vitis-idaea following fire.

Little shrub resprouting was observed during the growing season in which the experimental fires were conducted. By the end of September 1978, some sprouting of V. uliginosum occurred in the most lightly burned transects of Unit 1. This unit was burned on July 19, two to three weeks before the other units. Unburned Vaccinium as well as fire-pruned shrubs with portions of above ground stems still intact were found only in this unit. New sprouting of blueberry was observed on these transects as early as August 17, 1978, four weeks after fire. At this time, sprouting originated from lateral bud elongation on stems pruned above ground level.

Although other studies have noted the origin, (i.e. underground stem, basal sprouting, etc.) of shoots returning after fire (Miller 1977) the origin of these shoots was observed only because it was the first Vaccinium response to occur. This origin was not common since few plants survived the fire with portions of their above ground parts intact. Sprout origin was not determined for shoots originating

below the surface.

The greatest vegetation response was observed in the summer of 1979, the first growing season after fire. At this time, there was a rapid increase in numbers of sprouts for those species whose propagules survived the fires and for those species which had the ability to spread rapidly in the early postfire environment. Response was characterized by a change in species composition and a change in relative species abundance. Changes were found to vary with fire severity as had been previously reported (Viereck and Dyrness 1979; Foote 1976; Miller 1977).

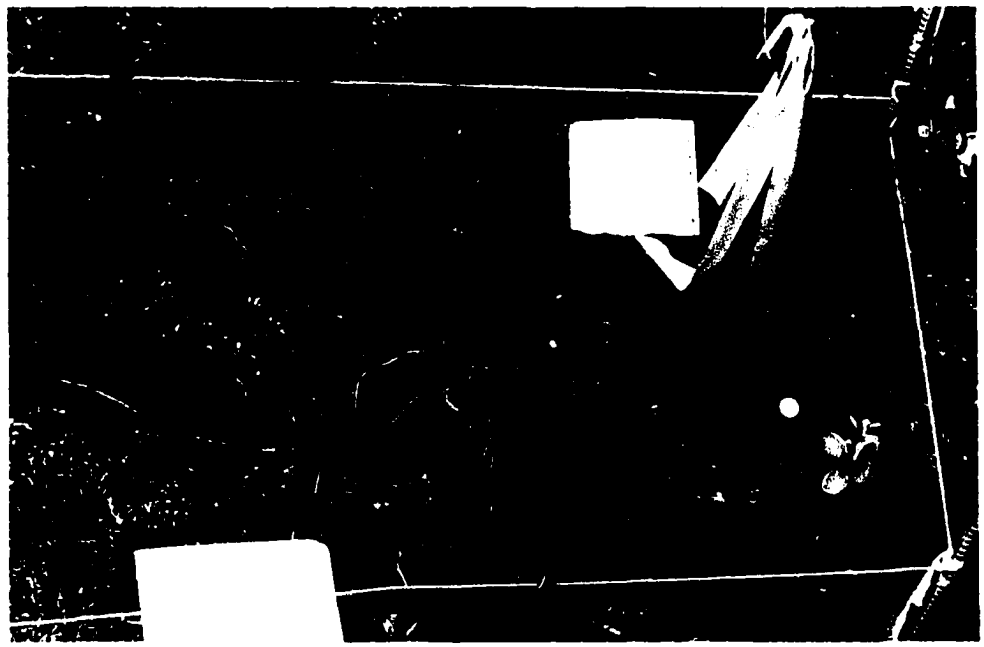
The range of Vaccinium response during the summer of 1979 was dramatic. The number of shoots on a $\frac{1}{2}m^2$ plot ranged from zero on heavily burned plots to over 200 shoots on lightly burned plots. In addition to plant density response over the growing season (Appendix B) plant response was also exhibited by change in height, number of leaves and complexity of stem architecture. Shoots appearing during 1979 did not produce flowers.

Second season response was very different from first season response. Most transects began the second growing season with fewer plants than were present at the end of the 1979 season because many shoots did not survive the first winter. During the summer of 1980, the rate of emergence of new shoots decreased and mortality increased. Shoots which

survived the second growing season continued to increase in growth and architectural complexity. The more robust shoots produced flowers and fruits by September 1980, however, phenophases were out of step with those observed in unburned plants. Although V. uliginosum produced mature berries by the end of the second growing season (1980), all berries observed on V. vitis-idaea were still small and green by the end of September. Flowering was observed for V. uliginosum at the same time it occurred in unburned plants near the experimental firea area. The transects were not visited at the time flowering was occurring in unburned V. vitis-idaea so it was not possible to compare the flowering phenophase in resprouted plants of this species with the time of flowering of unburned plants. Since berries did not mature by the end of the growing season, it was assumed that flowering in burned plants occurred later than flowering in unburned plants for lingonberry.

A general illustration of shrub response to fire severity is shown in Figs. 7 and 8. These photos were taken on a representative transect approximately one year after treatment. The photos show species and density response to fires of different severities. In Fig 7a, 4 shoots of V. uliginosum and 20 shoots of V. vitis-idaea were growing on the plot. Organic layer depth was 11.7 cm. The number of shoots prior to burning in this plot were 1 blueberry and 52 lingonberry.

Fig. 7. Photos of lightly burned plots one year after treatment. Vaccinium density was lower where the organic layer depth was 11.7 cm (a) than where the organic layer was 22.1 cm (b).



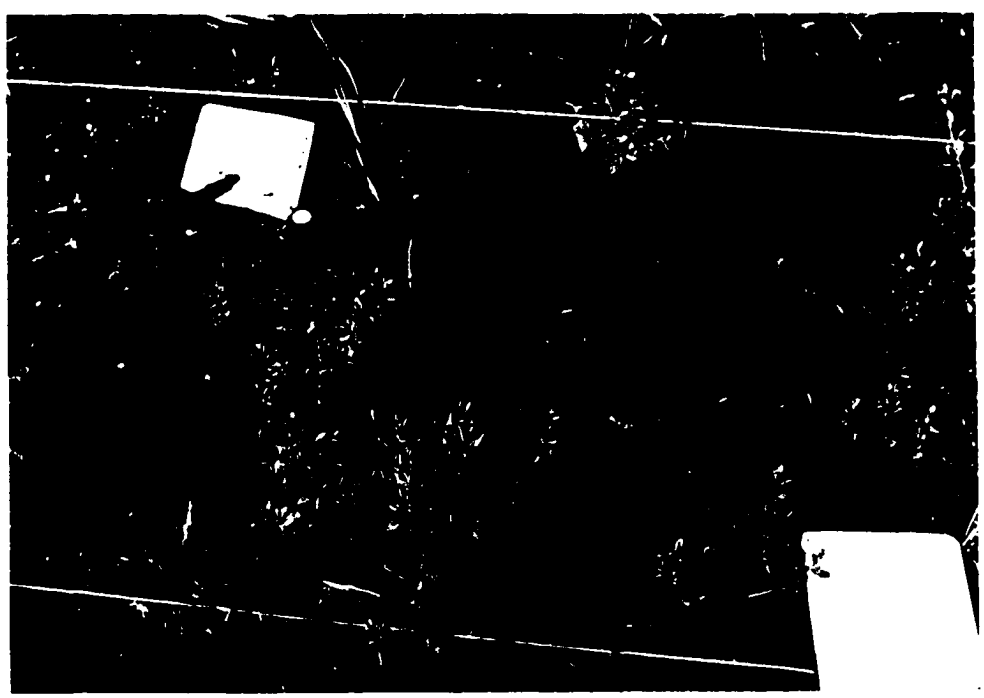


Fig. 8. Photos of moderately and heavily burned plots one year after treatment. Vaccinium shoots were not present where organic layer depth was 8.5 cm although Calamagrostis was common (a). Epilobium and Marchantia were prominent species where organic mat was 1.6 cm (b).

The densities of V. vitis-idaea and V. uliginosum in Fig. 7b are 25 and 120 respectively and residual organic mat depth was 22.1 cm. Preburn shoot numbers were 59 lingonberry and 21 blueberry. There were no Vaccinium shoots present on the plot in Fig. 8a, although Calamagrostis candadensis was common on this plot. The average organic layer depth was 8.5 cm. Before fire, 3 blueberry plants and 98 lingonberry plants occurred on this plot. No Vaccinium shoots were present in 1979 on the plot which had a residual organic mat of 1.6 cm (Fig. 8b). Preburn shoot density was 74 lingonberry and 7 blueberry. The prominent species present one year after fire were Epilobium angustifolium and Marchantia polymorpha.

Percent cover for all species one year after fire was compared to values of the depth of the residual organic layer (Table 2). The depth of the average residual organic layer in the transects with more than 1% cover for V. uliginosum was never less than 10.0 cm. Average residual organic layers in transects with more than 1% cover for V. vitis-idaea were never less than 8.4 cm. Transects with an average organic layer of more than 15.0 cm were covered primarily by ericaceous shrubs, which had a combined cover of about 20%. The major vegetational components in transects with less than 15.0 cm organic material were fireweed, Marchantia and mosses. Total fireweed cover in a severely

burned transect (average residual om = 5.0 cm) was as high as 44%. In other severely burned transects, moss cover composed of Polytrichum sp. and Ceratodon sp. ranged from 30 - 50%.

Blueberry and lingonberry density was related to the depth of the residual organic layer for one experimental transect (Fig. 9a). In this transect, maximum Vaccinium response occurred at the fourth $\frac{1}{2}m^2$ plot along the transect. This response coincided with maximum residual organic matter depth on the transect. No Vaccinium response was observed in the last two plots on the transect where average values for organic mat thickness were 8.5 and 1.6 cm. In an additional example from another transect, (Fig. 9b) no Vaccinium response occurred where residual organic mat depth was less than 10.1 cm.

Relationship of V. uliginosum and V. vitis-idaea Density to Fire Severity

The functional relationship between postfire Vaccinium density and fire severity was analyzed by regression techniques. Both simple linear and multiple linear regressions were per-formed. Results are discussed separately.

The first group of simple linear regression equations describes shrub response at the transect level (Table 4a). In these equations, the independent variable (X) was the depth of the residual organic material (a measure of fire

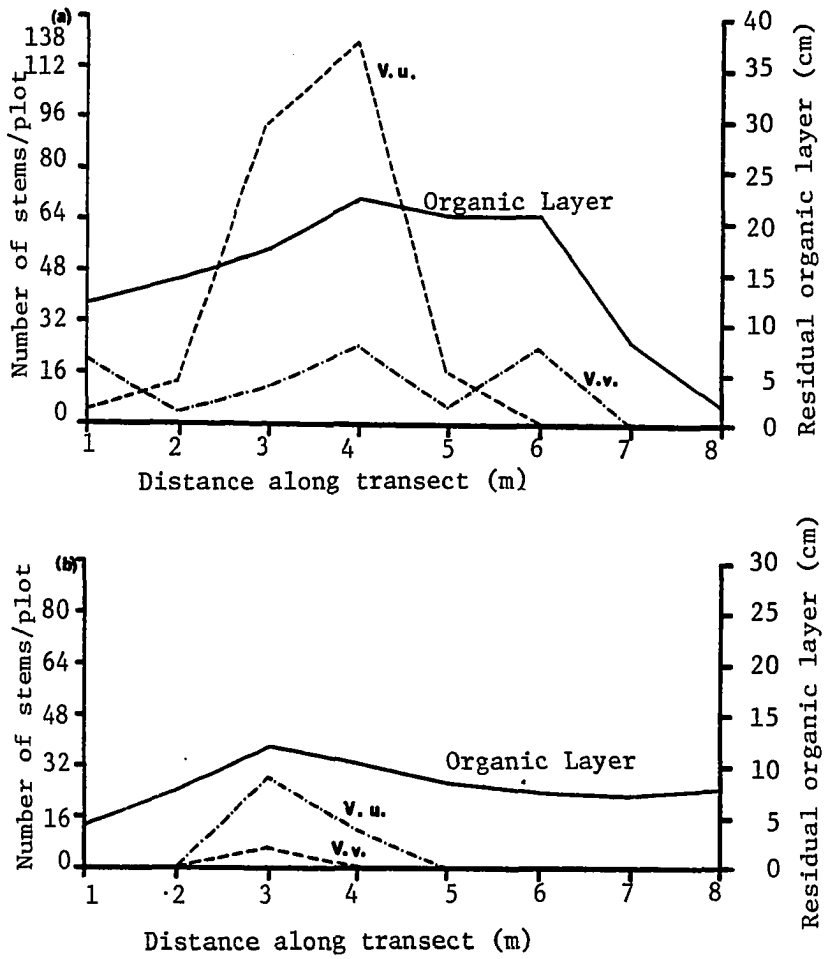


Fig. 9. Density of V. uliginsum (V.u.) and V. vitis-idaea (V.v.) related to the depth of the residual organic layer (solid line) for 2 transects. Right hand scale is depth of the residual organic layer (cm).

Table 4. Summary of regression analysis.

Y	a	b	R	R^2	F_{value}	Level of Significance P=
a) Simple linear regression, Y = ax + b N = 30 samples X = Residual organic mat (cm)						
1979						
V. uliginosum	-33.23	4.86	.72	.52	30.76	.01
Log V. uliginosum	.43	.12	.86	.74	53.87	.01
V. vitis-idaea	-39.83	6.01	.67	.45	23.27	.01
Log V. vitis-idaea	.43	.12	.84	.70	65.38	.01
1980						
V. uliginosum	-25.98	3.76	.70	.49	27.40	.01
Log V. uliginosum	.46	.11	.86	.74	80.99	.01
V. vitis-idaea	-37.15	5.19	.67	.45	20.67	.01
Log V. vitis-idaea	.34	.12	.83	.69	62.12	.01
b) Simple linear regression, Y = ax + b n = 232 samples X = Residual organic mat (cm)						
1979						
V. uliginosum	-20.91	3.69	.56	.31	103.26	.01
V. vitis-idaea	-18.40	4.03	.48	.23	67.01	.01
1980						
V. uliginosum	-15.84	2.80	.54	.29	95.75	.01
V. vitis-idaea	-16.39	3.62	.46	.22	63.43	.01
c) Simple linear regression, Y = ax + b n = 25 samples X = organic mat removed (percent)						
1979						
V. uliginosum	63.63	- .84	-.63	.40	15.50	.01
Log V. uliginosum	2.80	- .02	-.79	.62	37.87	.01
V. vitis-idaea	99.90	-1.45	-.82	.67	47.39	.01
Log V. vitis-idaea	3.01	- .02	-.89	.78	83.11	.01

Table 4. Continued

Y	a	b	R	R^2	F_{value}	Level of Significance P=
1980						
V. uliginosum	48.80	- .65	-.62	.38	14.01	.01
Log V. uliginosum	2.63	- .02	-.77	.59	33.38	.01
V. vitis-idaea	92.01	-1.34	-.82	.67	46.02	.01
Log V. vitis-idaea	2.98	- .03	-.90	.80	94.21	.01

Y	a	b	c	R	R^2	F_{value}	Level of Significance P=
d) Multiple linear regression, $Y = a + bx_1 + cx_2$							
n = 30 samples							
x_1 = Residual organic mat (cm)							
x_2 = Preburn density of Vaccinium							
1979							
V. uliginosum	-39.80	3.79	1.37	.76	.58	43.41	.01
Log V. uliginosum	.32	.10	.02	.89	.79	110.46	.01
V. vitis-idaea	-59.41	5.13	.29	.50	.25	13.76	.01
Log V. vitis-idaea	.30	.11	.01	.71	.50	32.85	.01
1980							
V. uliginosum	-30.83	2.97	1.01	.70	.49	31.75	.01
Log V. uliginosum	.37	.10	.02	.86	.74	81.71	.01
V. vitis-idaea	-54.54	4.82	.25	.50	.25	13.28	.01
Log V. vitis-idaea	.21	.12	.00	.70	.49	31.04	.01
e) Multiple linear regression, $Y = a + bx_1 + cx_2$							
n = 232 samples							
1979							
V. uliginosum	-26.31	2.97	.99	.50	.25	69.04	.01
V. vitis-idaea	-36.70	.34	2.52	.31	.09	50.39	.01
1980							
V. uliginosum	- 4.88	.76	.79	.34	.12	59.82	.01
V. vitis-idaea	-.40.07	3.29	.27	.33	.11	55.28	.01

Table 4. Continued

Y	a	b	c	R	R^2	F_{value}	Level of Significance P=
f) Multiple linear regression, $Y = a + bx_1 + cx_2$							
n = 25 samples							
x_1 = Organic mat removed (percent)							
x_2 = Preburn density of Vaccinium							
1979							
V. uliginosum	31.72	- .65	1.52	.68	.46	23.24	.01
Log V. uliginosum	2.35	- .02	.02	.77	.59	36.19	.01
V. vitis-idaea	54.44	-1.23	.36	.74	.54	30.59	.01
Log V. vitis-idaea	2.45	- .02	.00	.82	.68	51.06	.01
1980							
V. uliginosum	24.96	- .51	1.13	.62	.39	18.05	.01
Log V. uliginosum	2.24	- .02	.02	.72	.52	28.28	.01
V. vitis-idaea	52.52	-1.15	.31	.72	.51	28.44	.01
Log V. vitis-idaea	2.47	- .02	.00	.83	.70	55.46.	.01

severity). The highest R^2 values for this measure were for the log-transformed V. uliginosum densities for both 1979 and 1980. R^2 values were .74 for both years. R^2 values for V. vitis-idaea were .70 in 1979 and .69 in 1980. For untransformed data, R^2 was .59 in 1979 and .49 in 1980 for blueberry and .45 for lingonberry in both years.

Simple linear regression using the individual $\frac{1}{2}m^2$ plot densities yielded R^2 values lower than any at the transect level (Table 4b). For example, R^2 values for untransformed blueberry data in 1979 was .52 at the transect ($4m^2$) scale while at the plot ($\frac{1}{2}m^2$) scale, the R^2 value was .31. Log transformed data were not tested at the plot level. All equations were significant to at least P = .01 level.

The relationship between the percent of the total organic material removed and shoot production was analyzed only at the transect ($4m^2$) level of resolution (Table 4c). R^2 values were lower for this independent variable than for the residual organic mat in the case of blueberry. However, in the case of lingonberry, R^2 values were higher for percent organic mat removed than for the relationship between residual organic mat and shoot production. All log transformed data yielded higher R^2 values than untransformed data. All equations were significant at least at P = .01 (Table 4a, b and c).

Although the methods of measuring fire severity were

shown to be better for predicting the response of one species than another, as pointed out in the Methods chapter, these measurements were obtained in different ways. The average value of organic mat remaining on the transect was determined by taking the average value of 120 points from the transect, while the value for percent organic material removed was computed from only three points per transect (Fig. 2).

Multiple linear regression analysis was performed to determine if the addition of a second variable, preburn shoot density, would provide a more accurate predictive model than simple linear regression (Table 4d,e,f). Most all trends within the series of multiple linear regression equations followed the same trends as the simple linear regression equations. For example, on the transect level (Table 4d), the equations with the best "fit" in the series were for log-transformed V. uliginosum data. Values obtained using the independent variable, the percent of organic mat removed (Table 4f), were also higher for lingonberry data and lower for blueberry data, just as found for the simple linear regressions. On the plot scale ($\frac{1}{2}m^2$), the overall best "fit" was again found for V. uliginosum, 1979 data (Table 4e). All multiple linear regression equations were significant to the P = .01 level (Table 4d, e, and f).

A comparison of R^2 values for simple linear regression

equations and multiple linear regression equations (Table 5) shows that the addition of the preburn density variable did not generate more significant equations than were obtained for the simple linear regressions. At the transect level, all R^2 values obtained from multiple linear regression for both values of the variable measuring fire severity were lower than values obtained from the simple linear regression except in the case of V. uliginosum, 1979.

A possible explanation as to why the addition of the number of preburn stems did not improve the "goodness of fit" of the shrub response equations is that over half of the plots had a severe reduction in the organic layer and no shrub regrowth during the two postfire years. In this case, prefire numbers had no importance since all below ground plant parts were killed. The importance of preburn density of Vaccinium may increase in the more lightly burned plots, where more below ground plant material survived the fires. In order to determine if this was true, multiple linear regression was run for 50 ($\frac{1}{2}m^2$) plots having a residual organic layer depth of 15 cm or greater. The R^2 value found for V. uliginosum 1980 data was .31 in this case. This R^2 value was slightly higher than that obtained for V. uliginosum 1980 values for all 232 $\frac{1}{2}m^2$ plots (Table 5).

Table 5. Comparison of R^2 values for regression analysis of *V. uliginosum* and *V. vitis-idaea* in 1979 and 1980.

	Transect Level ($4m^2$)				Plot level ($1/2m^2$)	
	Simple Linear Regression		Multiple Linear Regression		Simple Linear Regression	Multiple Linear Regression
	X = Residual organic mat (cm)	X = Organic mat removed (percent)	X = Residual organic mat (cm)	X = Organic mat removed (percent)	X = Residual organic mat (cm)	X = Residual organic mat (cm)
1979						
V. uliginosum	.52	.40	.58	.46	.31	.25
Log *V. uliginosum*	.74	.62	.79	.59		
V. vitis-idaea	.45	.67	.25	.54	.23	.09
Log *V. vitis-idaea*	.70	.78	.50	.68		
1980						
V. uliginosum	.49	.38	.49	.38	.29	.12
Log *V. uliginosum*	.74	.59	.74	.52		
V. vitis-idaea	.45	.67	.25	.51	.22	.11
Log *V. vitis-idaea*	.69	.80	.49	.70		

ASPECTS OF VACCINIUM AUTECOLOGY AND GROWTH

What aspects are there of the biology and ecology of V. vitis-idaea and V. uliginosum which may help to explain these species' response to fire? The results of several different investigations are combined here in order to describe properties of these species which aid in the re-establishment after fire.

Underground Structure of Vaccinium

Calmes and Zasada (in press) estimated that blueberry clones covered an area of 5 to 10 m^2. The number of above ground shoots per clone ranged from 8 to 13. The size of clones for V. vitis-idaea could not be determined from my search of the literature or from my own observations. Tear (1972) found that the total number of shoots per plant in forest habitat was 3 to 4, while plants growing in open areas had 9 to 16 shoots per clone. Tear attributed the difference in the number of shoots to a monopodial rhizome system in forest habitat as compared to a sympodial system in open habitat. The number of shoots per clone found by Tear may be low compared to values observed in Alaska.

The buried plant parts of V. uliginosum were found to be located in the upper two thirds of the organic layer, 15 - 20 cm below the surface. (Calmes and Zasada in press). Excavation done during this experiment confirmed these findings. The location of the below ground lingonberry rhizomes

was found to be shallower and generally located in the upper half of the organic layer, 5 - 10 cm below surface. Some overlap occurred for the two species. Ritchie (1955) found lingonberry rhizomes to be located 10 - 20 cm below surface.

The depth of underground plant parts has been used to predict species response during fires of different severities. (Flinn and Wein 1977; McLean 1968; Miller 1977). Information and personal observations for blueberry and lingonberry may be used to postulate theoretical differences in survival of the two species (Table 6). The purpose of Table 6 is to help explain how differential survival may have occurred between the two species. Since V. vitis-idaea appears more susceptible to fire damage due to its shallower rhizome system, the expected outcome would be a more severe decrease in V. vitis-idaea shoot numbers than in V. uliginosum numbers. The table is only a theoretical model of survival based upon postburn depth of the organic layer, although in nature, exposure to temperatures above 60^{o} c (Precht et al 1973) kills plant tissue. This has been shown to be true from field results since often a considerable amount of the original organic mat remained yet no shrub response occurred.

As for any species with clonal growth, survival of Vaccinum must be viewed at two levels, that of the ramet and the genet (Harper 1977). When information concerning the size and extent of Vaccinium clones is combined with in-

Table 6. Theoretical difference in survival of two species of *Vaccinium*[1]

Fire severity Category	% Area	Average Postburn depth (cm)	Theoretical consumption of plant parts to this depth below surface[2]	Theoretical consumption of plant organs	
				V. uliginosum	*V. vitis-idaea*
Unburned	4.0	25.0 cm	.0 cm	None	None
Singed	7.5	21.6 cm	3.6 cm	Partial pruning of aerial shoots	Partial pruning of aerial shoots
Light	35.0	19.8 cm	5.4 cm	Pruning of all aerial shoots	pruning of all aerial shoots and partial consumption of rhizomes
Moderate	30.1	9.5 cm	15.7 cm	Partial consumption of shallow buried stems	Complete consumption of all rhizomes
Heavy	23.4	6.0 cm	19.2 cm	Most all buried stems consumed	Complete consumption of all rhizomes

[1]Values in first 4 columns is from C. T. Dyrness, personal communication.
[2]Based on the average unburned depth of 25.2 cm for all units.

formation about the scale at which the range of fire severity occurred, more specific information may be deduced concerning Vaccinium survival during fire. Since so much variation in fire severity occurred across a $4m^2$ transect (Fig. 4) and since blueberry clones were found to cover an area of 5 - 10 m^2, the chances for destroying an entire clone would be low even in areas of heavy burns. Although information is incomplete regarding the horizontal distribution of lingonberry clones, this deduction may similarily hold for this species. The smaller the area the clone occupies, however, the greater the chance for fire consumption of an entire genet.

Ability to Produce Shoots

The clipping study indicated that the two Vaccinium species differed in their ability to produce shoots following mechanical disturbance (Table 7). Blueberry had more than twice as many shoots ($1.7 \pm .3$) per labeled "stump" as lingonberry ($0.6 \pm .2$) one year after clipping treatment. Shoot density one year after clipping followed a similar trend with blueberry returning to $92 \pm 30\%$ and lingonberry to $66 \pm 30\%$ of predisturbance density (Table 7).

The observed response of Vaccinium in burned plots consisted of shoots originating from the fire pruned root collars at the surface of the organic layer (stump sprouts) and from shoots originating from the below ground system. The clipping

Table 7. Results of Vaccinium Clipping Study

Treatment	Date	Series	Number of Shoots M^2 (% original #)[1) 1979		1980		Number of Shoots per Stump 1979		1980	
Vaccinium uliginosum										
	30 May 1979	A	213	49	149	49	2.4	.5	2.3	.4
	12 Jun 1979	B	145	28	102	6	1.8	.1	1.7	.1
	25 Jun 1979	C	109	15	94	17	1.7	1.1	1.8	.2
	17 Jul 1979	D	90	18	82	20	1.1	.4	1.5	.5
	30 Jul 1979	E	20	16	55	3	.5	.3	1.5	.1
	6 Aug 1979	F	0		68	40	.1	.1	1.7	.6
	13 Aug 1979	G	0		91	36	0	0	1.2	.2
Average =			82	80	92	30	1.1	.9	1.7	.3
Vaccinium vitis-idaea										
	30 May 1979	A	108	31	126	35	.9	.1	1.1	.2
	12 Jun 1979	B	82	30	87	28	.5	.1	.3	0
	25 Jun 1979	C	55	11	59	14	.4	.2	.6	.4
	17 Jul 1979	D	21	28	64	11	.3	.1	.6	.2
	30 Jul 1979	E	0		40	8	0		.6	.2
	6 Aug 1979	F	0		42	3	0		.5	.1
	13 Aug 1979	G	0		47	10	0		.8	.2
Average =			38	44	66	31	.3	.3	.6	.2

[1)] Number of shoots are followed by standard deviation.

study results only consider stump resprouting. Although resprouting from below ground plant parts was not quantified, exploratory excavations of lingonberry clones showed that rhizome sprouting did occur. Rhizome sprouting may represent a more delayed response than resprouting from root collars, particularily in the absence of preformed bud initials.

Response to fire is possible from all dormant meristems above and/or below ground. This meristematic material makes up the total "bud bank" (Harper 1977). Information from the literature and this study reveals that the available "bud bank" differs in size and distribution for the two Vaccinium species.

Mechanisms for clonal expansion also differ for these species. V. uliginosum clones expanded through a process similar to layering in black spruce while V. vitis-idaea spread by the elongation of fleshy rhizome tips growing below the surface (Calmes and Zasada in press). These differences in means of clonal expansion suggest that these species differ in their ability to recolonize severely burned sites by vegetative means. Clones of Vaccinium myrtillus, a rhizomatous species, were capable of expanding radially at about 7 cm per year although some rhizomes grew much faster (Flower-Ellis 1971). Rates of expansion of V. vitis-idaea were not found in the literature. Since V.

uliginosum is not rhizomatous, the rate of re-invasion of this species would depend upon a two step process. The first step would depend upon the rate of shoot growth possible in a growing season and the second step would depend upon the rate at which the shoots could become covered by moss or debris. Shoot growth for fire treated plants was as much as 24 cm for some sprouts one year after fire, but growth was less for the second year. Shoot growth for unburned plants was not observed in this study.

Effect of Season by Disturbance of Resprouting

By the end of 1979, the same growing season that clipping occurred, there was a constant decline in the number of shoots produced with each successive clipping date (Table 7, Figs. 10 and 11). For V. vitis-idaea the only plots to have greater than the original number of shoots were those clipped on May 30 (108% $\pm$ 31% of the original number). The second clipping series had 82 $\pm$ 30% of the original number of shoots. The third series had 55 $\pm$ 11% and the fourth series had 21 $\pm$ 28%. The fifth clipping series, administered on July 30, had no significant resprouting.

One year after clipping, the effect of time of disturbance was not as obvious for lingonberry as in 1979 because plants clipped in late summer sprouted during the growing season of 1980. The increase in shoot numbers for late

season treated plots (Fig. 10) did not equal the response for early treated plots. The first series(May 30) still had a greater number of resprouted stems than were originally on the plots.

The 1979 response for V. uliginosum (Fig. 11) declined for each subsequent clipping date although the decline was less constant than for V. vitis-idaea (Table 7 and Fig. 10). Plots treated first (May 30) were 213 ± 49% original density value. Second treatment response was 145 ± 28%. Third treatment response was 109 ± 15%. Fourth was 90 ± 18% and fifth was 20 ± 16% of the original density of stems. No significant resprouting of V. uliginosum occurred after August 6. The first three clipping series for blueberry had more stems than were present before clipping by the end of 1979.

At the end of the 1980 field season, V. uliginosum exhibited a decreased number of shoots for early season plots and an increased number for late season plots when compared to regrowth in 1979 (Fig. 11). Response for this species was different than that for lingonberry response since all lingonberry values were slightly to significantly higher in 1980 than they were in 1979. The opposing trends of shoot mortality on early season plots and increased response of late season plots ameliorated the effect of clipping date upon the ability of V. uliginosum to return to a site. By

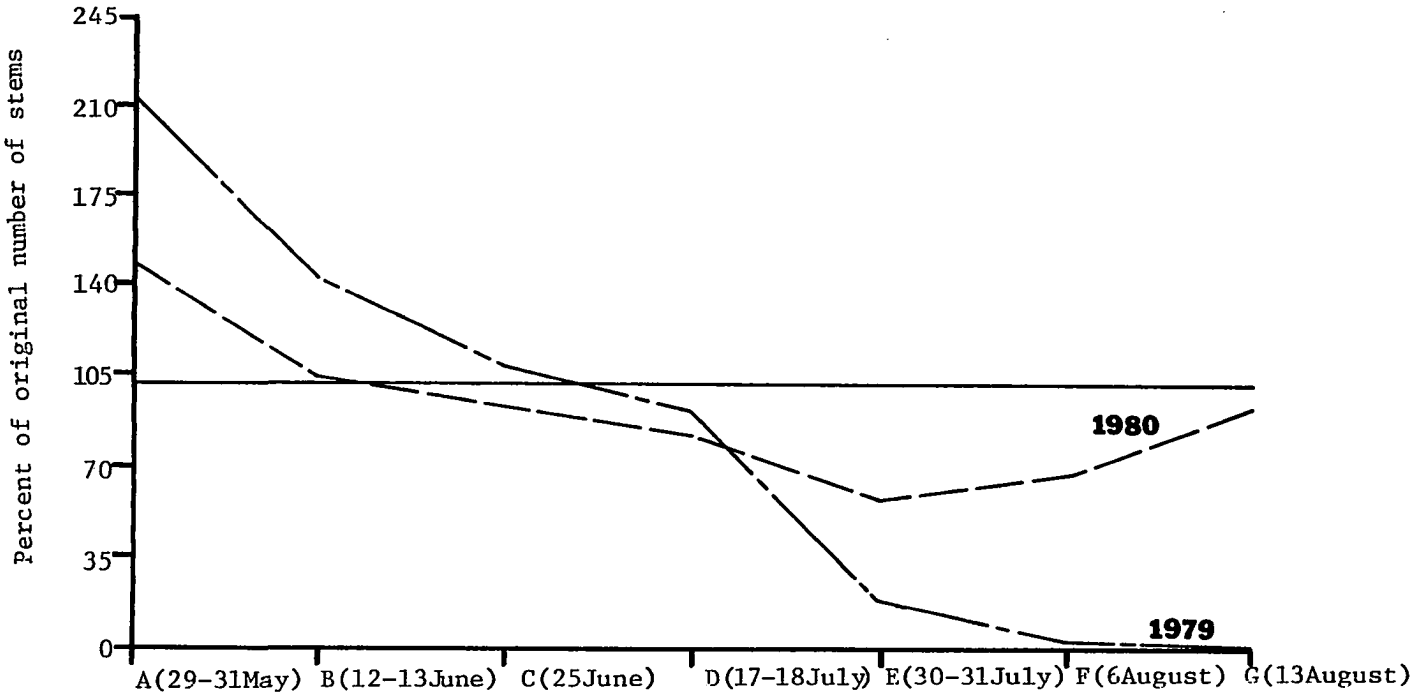


Fig. 10. Effect of date of clipping on resprouting of V. vitis-idaea. Response for the same year of treatment (1979) and response one year after treatment (1980). Solid line equals 100% of the original number of stems.

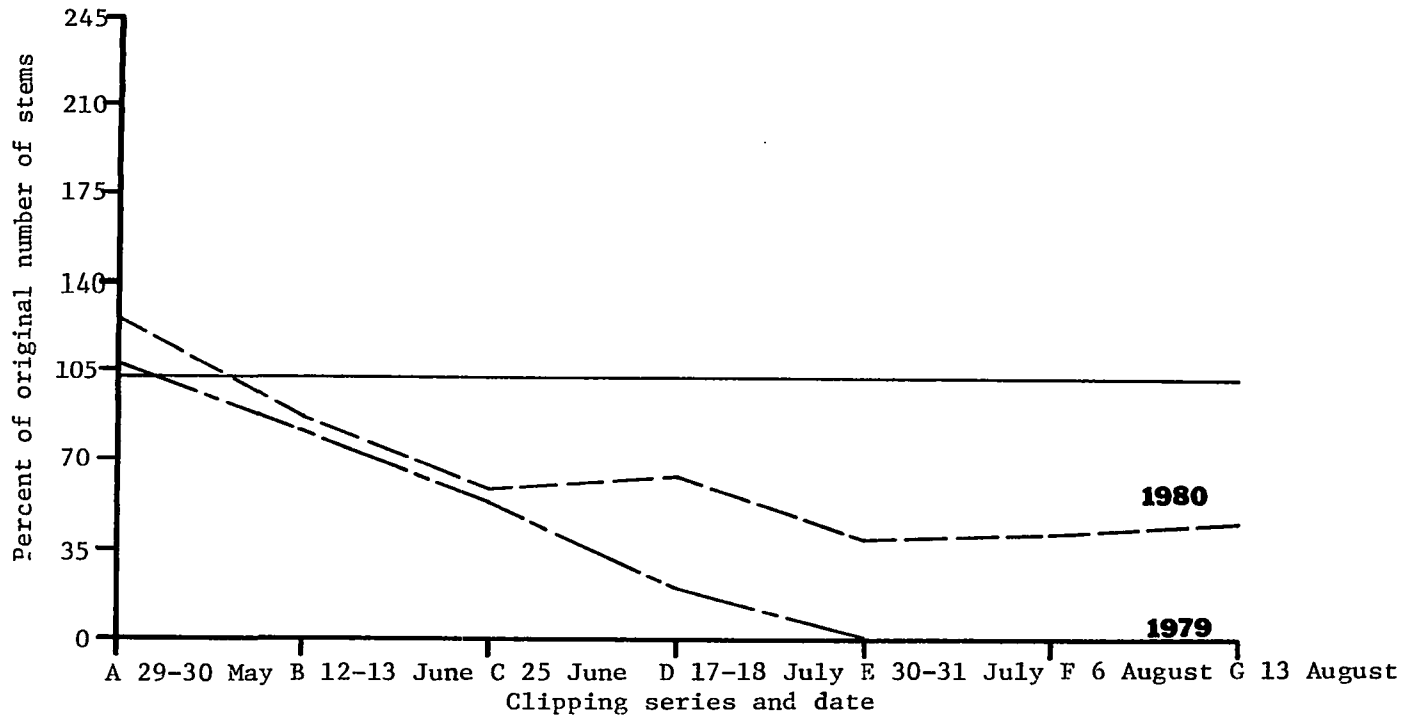


Fig. 11. Effect of date of clipping on resprouting of V. uliginosum. Response for the same year of treatment (1979) and response one year after treatment (1980). Solid line equals 100% of the original number of shoots.

the end of the 1980 growing season, the two earliest clipping series were the only series to have produced more shoots than unclipped plots.

A comparison of the means for the percentage of the original number of shoots treated before and up to July 17, 1979 to the number of shoots resulting from treatment after July 17, 1979 showed that the means were significantly different in August 1980, a little more than one year after treatment. For lingonberry, the mean number of shoots for early season plots was 84% of the original number of shoots, late season plots, 48%. This difference was significant at P = .01 level. Early season means for blueberry were 107%, late season means were 74% (Significant at P = .01 level).

The effect of the time of burning has been investigated by other workers. Some have reported results which were different than those presented here. Vaccinium angustifolium was found to resprout almost equally after both spring and autumn pruning (Black 1963; Eaton and White 1960; Smith and Hilton 1971). Miller (1978) found results that were similar to results in this study, in that reductions in shoot development of Vaccinium myrtilloides occurred for plants clipped after July 8 one year after treatment.

Comparison of Clipped and Burned Treatment

The clipping study performed in 1978, at the same time

as the experimental fires, compared the effects of mechanical pruning (clipping) and burning upon Vaccinium. Previous studies that compared the effects of mechanical pruning by clipping to burning showed that alteration of the microclimate and edaphic conditions during burning have caused increased plant performance. Standing crop of biomass (g/m) for Vaccinium angustifolium was 57% higher for a "straw burn" treatment than a clipping treatment administered during the summer. (Smith and Hilton 1971). Miller (1977) described a relationship between pruning depth and plant density in which the effects of fire pruning caused a positive response up to a certain point. Beyond that point, the effect of fire caused more damage to the buried plant parts and a decrease in the number of sprouts.

The overall effect of burning upon the transects was to produce a response which was less than the average response to clipping (Table 8). Burned blueberry density was 145% of the original density of stems while response to clipping was 183% in 1979. Response was 110% and 141% in 1980 for burning and clipping respectively. Lingonberry response was also less in burned than in clipped plots (25% compared to 60%) in 1979 and in 1980 (23% compared to 57%). However, when viewed at smaller scales ($4m^2$ transects for example) the overall response is a net response made up of the negative response in microsites where all the organic matter

Table 8. A comparison of clipping and fire treatment on resprouting of *V. uliginosum* and *V. vitis-idaea*.

	Vaccinium uliginosum			*Vaccinium vitis-idaea*		
	Treatment	Organic Material	% of original no. of shoots	Treatment	Organic Material	% of original no. of shoots
1979						
	Clipping	25.2 cm	183	Clipping	25.2 cm	60
	Burned	11.0 cm*	145	Burned	11.0 cm*	25
	Burned	17.8 cm	284	Burned	17.8 cm	64
	Burned	9.6 cm	132	Burned	15.8 cm	76
1980						
	Clipping	25.2 cm	141	Clipping	25.2 cm	57
	Burned	11.0 cm*	110	Burned	11.0 cm*	23
	Burned	17.8 cm	231	Burned	17.8 cm	77
	Burned	9.6 cm	131	Burned	15.8 cm	60

*Taken for average of all units.

was consumed by fire and the positive response in plots where the below ground plant parts were unharmed.

By using examples from individual transect data, it is possible to compare clipping treatment to a variety of burning treatments. The burning treatment which resulted in a residual organic layer of 17.8 cm for one $4m^2$ transect pruned the above ground stems of Vaccinium but did not decrease the organic layer greatly. The number of Vaccinium stems produced on this transect were a higher percentage of the original number of stems on the transect than the percent change that was produced by clipping (Table 8). Change in percent of fire treated blueberry exceeded values for clipped stems by 55% in 1979 and 64% in 1980. Response to fire exceeded response to clipping for lingonberry on this particular transect by 7% in 1979 and 35% in 1980. In this situation, the effects of fire upon soil and microclimate as described in the literature probably contributed to the improved shrub response (Viereck and Schandelmier 1980; Viereck and Dyrness 1979).

In a second example, a transect with a postfire response similar to a clipping response was chosen to show the kind of burning treatment for each species that might yield results similar to clipping (Table 8). For V. uliginosum, a response generally similar to clipping was observed in a $4m^2$ transect subjected to a burning treatment which resulted in

an organic layer 9.6 cm thick. In this transect the positive shoot response by the fire pruned blueberry plants is modified by the detrimental effect of killing the shallower underground stems. The transect found for lingonberry in which the response to fire was comparable to that of a clipping treatment was the transect with the postfire organic layer of 17.8 cm for the 1979 response and a transect with a postfire organic layer of 15.8 cm for the 1980 response. Since the underground system of V. vitis-idaea is shallower than V. uliginosum, a burn which leaves a greater amount of organic material unharmed is required for V. vitis-idaea than for V. uliginosum in order to produce the same number of shoots as a clipping treatment.

POPULATION DYNAMICS OF VACCINIUM

> "A biology of populations is a study of the number of organisms"
>
> J.L. Harper, 1977

Dynamics of Shoot Populations

The change in the total number of shoots on all transects indicated that the overall appearance of shoots followed the generalized pattern for most biological activity namely slow initial activity followed by a high rate of activity in mid-season and a reduction in late season (Fig. 12). Between June 3 and July 1, there was a relatively low rate of shoot emergence. This was followed by a more rapid rate of

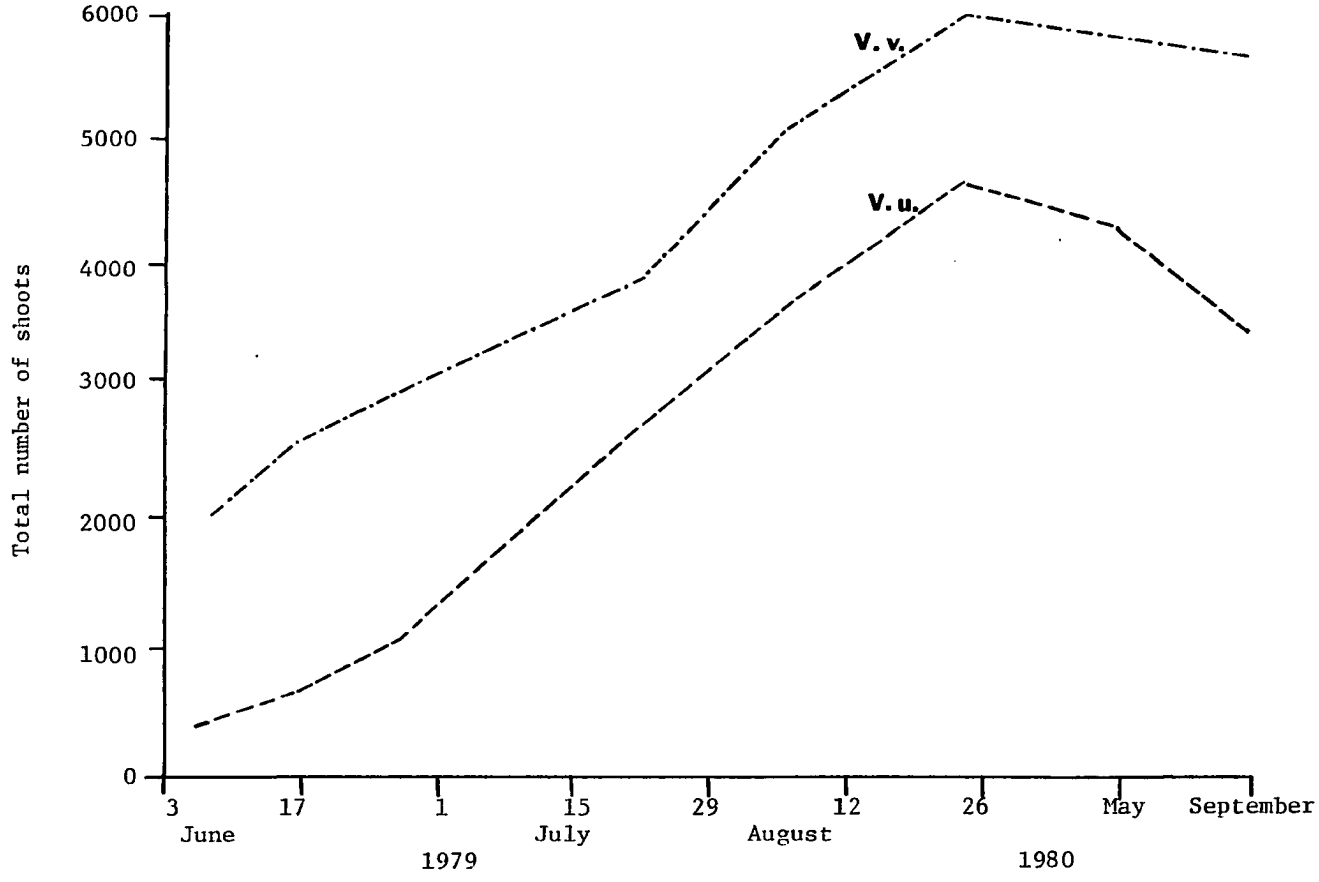


Fig. 12. Dynamics of shoot populations curves. Nubmer of live shoots present of V. uliginosum (V.u.) and V. vitis-idaea (V.v.) on all transects for the period between June 1979 and September 1980.

shoot emergence which continued until the first week of August. After this time, the rate of shoot emergence declined (Fig. 12 and Appendix B). The number of shoots present on August 27 represented the net production of shoots during the first growing season. This production was comprised of the number of unburned shoots on the transects at the beginning of the growing season, plus the "births" on the burned transects minus the "deaths" during the 1979 growing season.

The number of live stems present in May 1980 was lower than the number of stems present in August 1979. The net change represented those shoots which did not survive during the winter. In September 1980, the net number of living shoots was lower than in May 1980. The reduction in numbers for both species during the 1980 growing season was due to a decline in the rate of shoot production and an increase in shoot mortality.

The production of shoots for blueberry and lingonberry was generally comparable in rate and dates of maximum and minimum shoot numbers (Fig. 12). Several differences exist, however, between species. First, production of new blueberry shoots was greater than the production of new lingonberry shoots for 1979. Between the beginning of June 1979 and the end of August, the total number of blueberry shoots increased from 407 to 4600, a net gain of 4193 shoots (91%

gain). During the same period, lingonberry changed from 2462 to 5977, a net gain of 3530 shoots (41% gain).

During 1980, V. uliginosum experienced a greater decline in shoots than V. vitis-idaea. Lingonberry stems decreased from 5977 in August 1979 to 5428 in September 1980, a decrease of 9%. Blueberry stems decreased from 4600 in August 1979 to 3473 in September 1980, a decrease of 24% (Fig 12).

Another difference between species was the rate of shoot emergence during 1979. Shoots appeared at a uniform rate throughout the growing season for lingonberry (slope of curve = .34 - .36). Blueberry shoots appeared at a more rapid rate (slope = .69) from June 6 to July 24 than between July 24 and August 27 (slope = .29). These results indicated a species difference in seasonal response which may be related to the way in which shoots are produced in these species.

The curve of the dynamics of shoot population for blueberry and lingonberry (Fig. 12) represents the net changes in the number of shoots of these species. The fundamental equation of population biology (Ricklefs 1979), which is:

"$N_{t+1} = N_t$ + Births - Deaths + Immigrants - Emigrants"

illustrates that population size is composed of several variables including the birth of new organisms and the death of organisms removed from the population by density dependent

or density independent factors. The mortality of shoots as well as the birth of new shoots is incorporated in the net response (Fig. 12). What is not visible from a graph of net response (Fig. 12) is the actual proportion of new or dead shoots which make up the total response.

The net overall gain of blueberry shoots for 1979 was 4193 shoots. This resulted from the production of 4430 new shoots and the death of 237 shoots. Mortality for blueberry during 1979 was 5%. The net gain of lingonberry shoots was 3515; 3760 new shoots were produced and 245 shoots died during the growing season. Mortality for lingonberry was 7%.

Actual shoot production, i.e., "births" during 1979 has been plotted for one transect to illustrate the seasonal response in these species (Fig. 13). In this figure, the numbers of shoots produced during a two week period are shown to increase rapidly during the early part of the summer. Maximum production of shoots occurred towards the end of July. After this period, production leveled off. Shoot production declined sharply after the first week in August (Appendix B).

One may again refer to the analogy of the parent who leaves and later reclaims the child at the ticket booth for the roller coaster ride to describe viewing changes in Vaccinium populations at the level of response for all

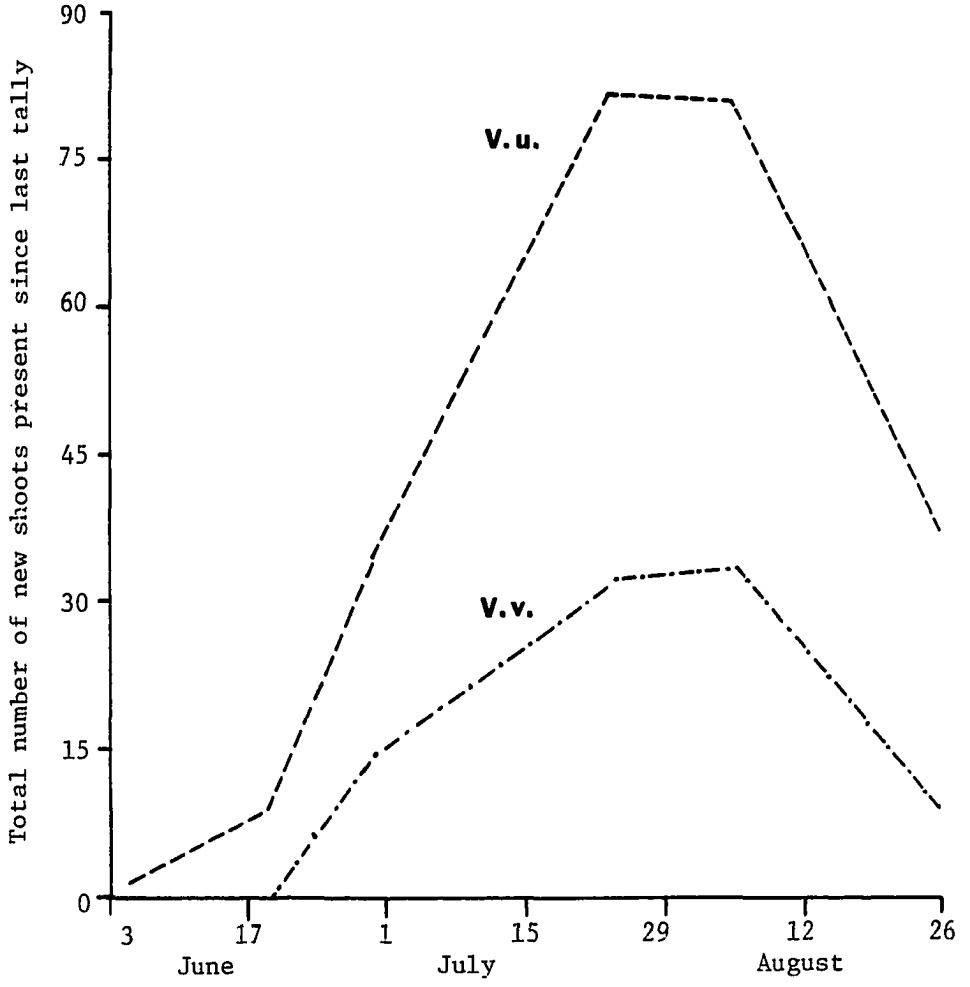


Fig. 13. Actual shoot production ("births") for one transect during the 1979 growing season.

transects combined (Fig. 12), that is one gets the feeling that the child has experienced ups and downs but does not know for sure what has happened. The total values used to show changes in Vaccinium densities concealed the fluctuations which occurred at smaller scales.

The generalized curves for V. vitis-idaea and V. uliginosum consisted of changes in the numbers of shoots from all the transects. These curves do not reveal that changes are occurring at smaller levels of resolution. For example, the decline for all transects combined shown for V. vitis-idaea during 1980 (Fig. 12), does not reflect that on an individual transect, the number of shoots may have actually increased.

The next example focuses on Vaccinium response at a unit level of resolution (five transects per unit). The generalized shape of the shoot population dynamics curve was common for all units (Figs. 14, 15 and 16). The transects in a unit have no obvious biological relation but were burned on the same day. In general, periods of population expansion and contraction occurred across all units at similar dates although some units, such as Unit 6, did not exhibit sprouting until July 1, well after sprouting had begun in other transects. Curves also differed in density response (amplitude) which was due to severity of burn.

It is convenient to contrast shrub response at the unit

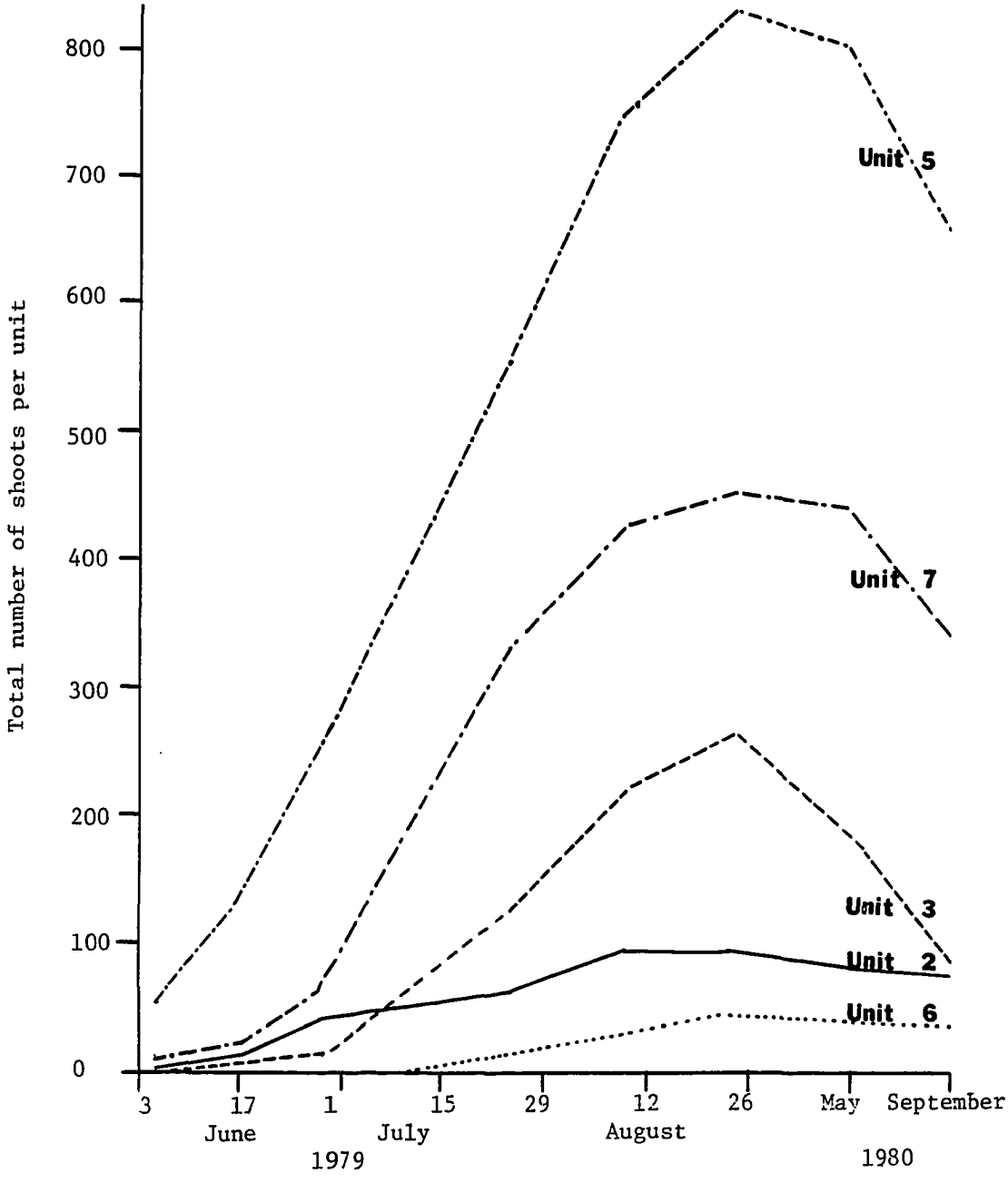


Fig. 14. Dynamics of shoot populations curves. Number of live shoots present of V. uliginosum within each unit. Curves differed in density response due to severity of burn.

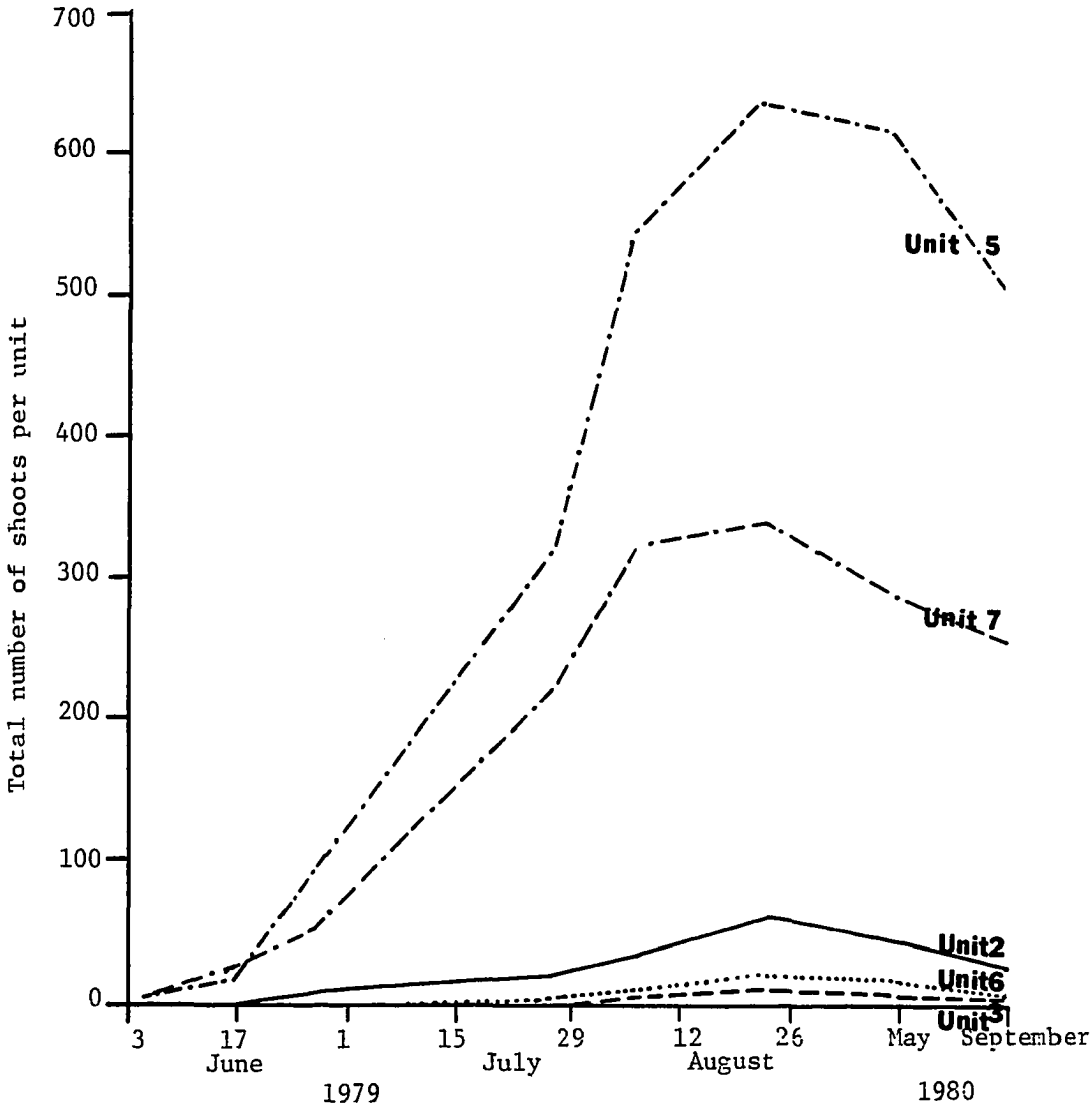


Fig. 15. Dynamics of shoot populations curves. Number of live shoots present of V. vitis-idaea within each unit. Curves differed in density response due to severity of burn.

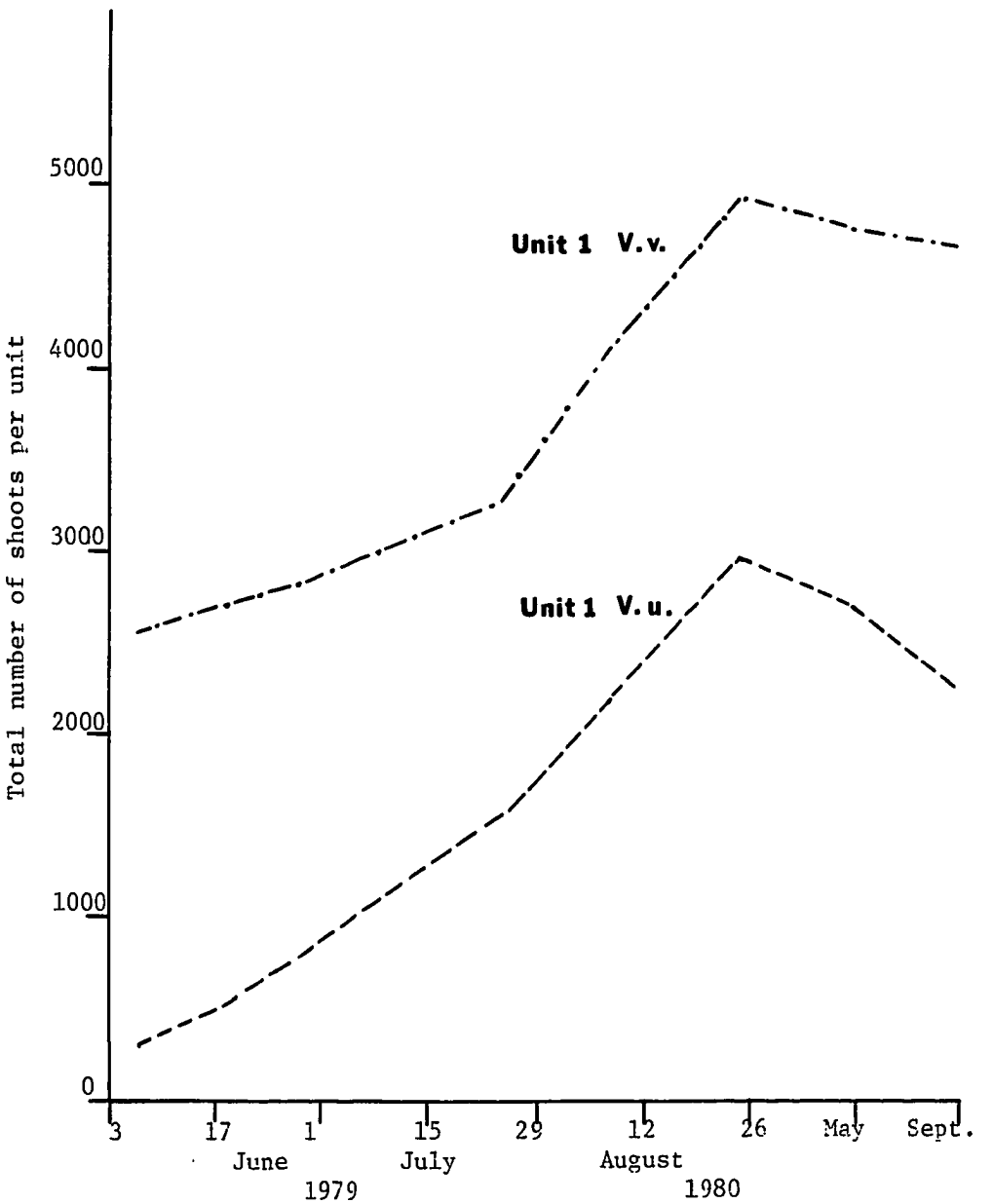


Fig. 16. Dynamics of shoot populations curves. Number of live shoots of both species, V. vitis-idaea (V.v.) and V. uliginosum (V.u.) in Unit 1.

level, but as demonstrated earlier, variations in fire severity occurred at a much smaller scale. Using a more powerful magnification brings to view Vaccinium response at a finer level of resolution, such as response on individual transects (Fig. 17, Appendix B). The transect was composed of eight contiguous, $\frac{1}{2}m^2$ plots, which may have been related to one another biologically since a particular clone may span more than one plot. The shoot population dynamics curve for one transect (Fig. 17) is generally similar in shape to the curves for the broader levels although the number of shoots of V. vitis-idaea increased over the 1980 growing season. (Preburn and postburn densities for all plots are presented in Appendix A) Mortality data for lingonberry in the transect under discussion indicates that the net increase was due to 25 new stems and the death of 18 stems.

The finest resolution available is at the plot level ($\frac{1}{2}m^2$). Using information about the size and distribution of clones, plots may be viewed as composed of any number of ramets from the same or several different genets. Shoot density for V. uliginosum (Fig. 18) ranged from zero (plot 7, not shown) to 120 (plot 4) shoots per plot in 1979. Although V. uliginosum values for plot 3 and plot 4 differed by 27 shoots at the end of 1979, the difference decreased by the end of the 1980 season when shoot density differed by

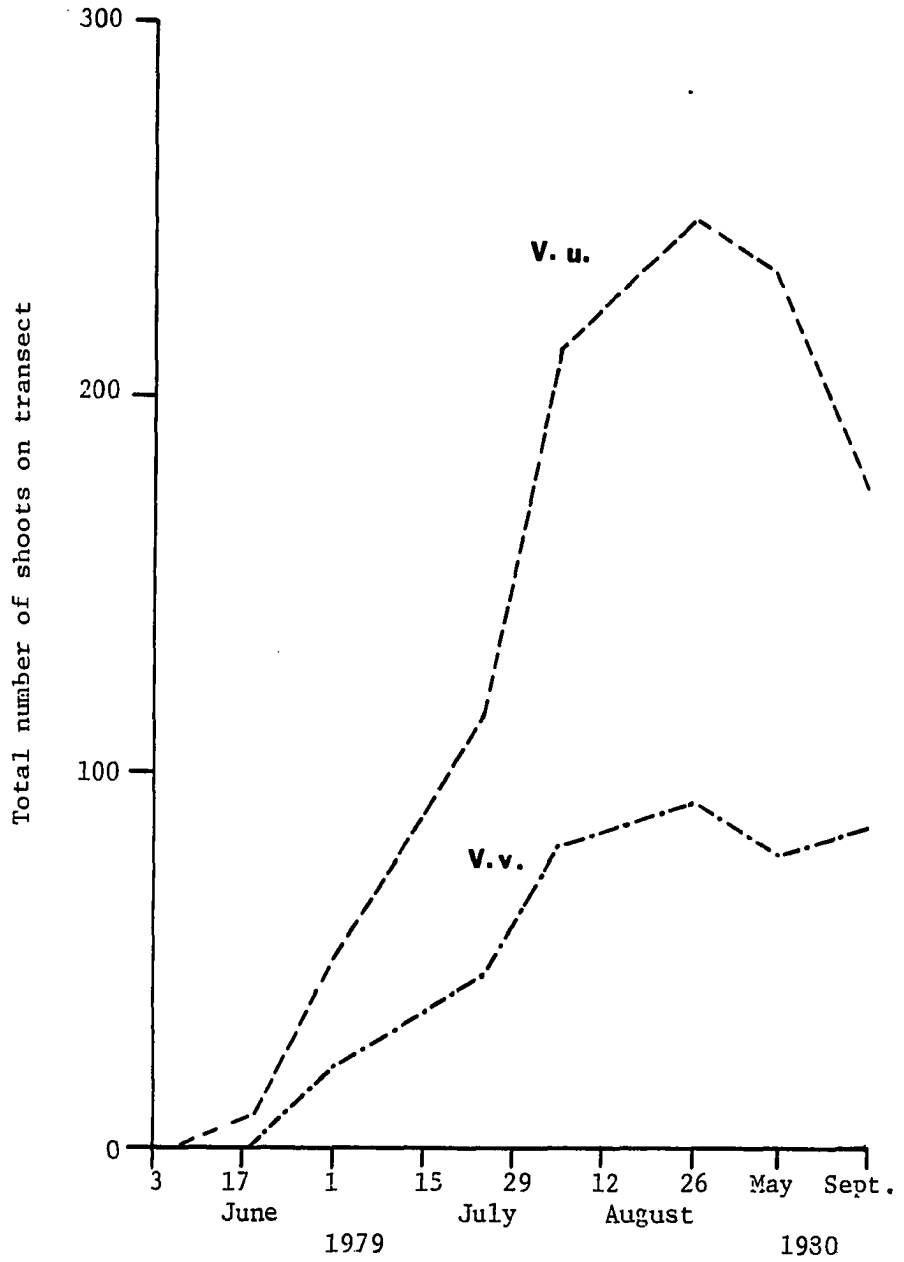


Fig. 17. Dynamics of shoot populations curves. Numbers of live shoots of both species, V. uliginosum (V.u.) and V. vitis-idaea (V.v.) for one transect.

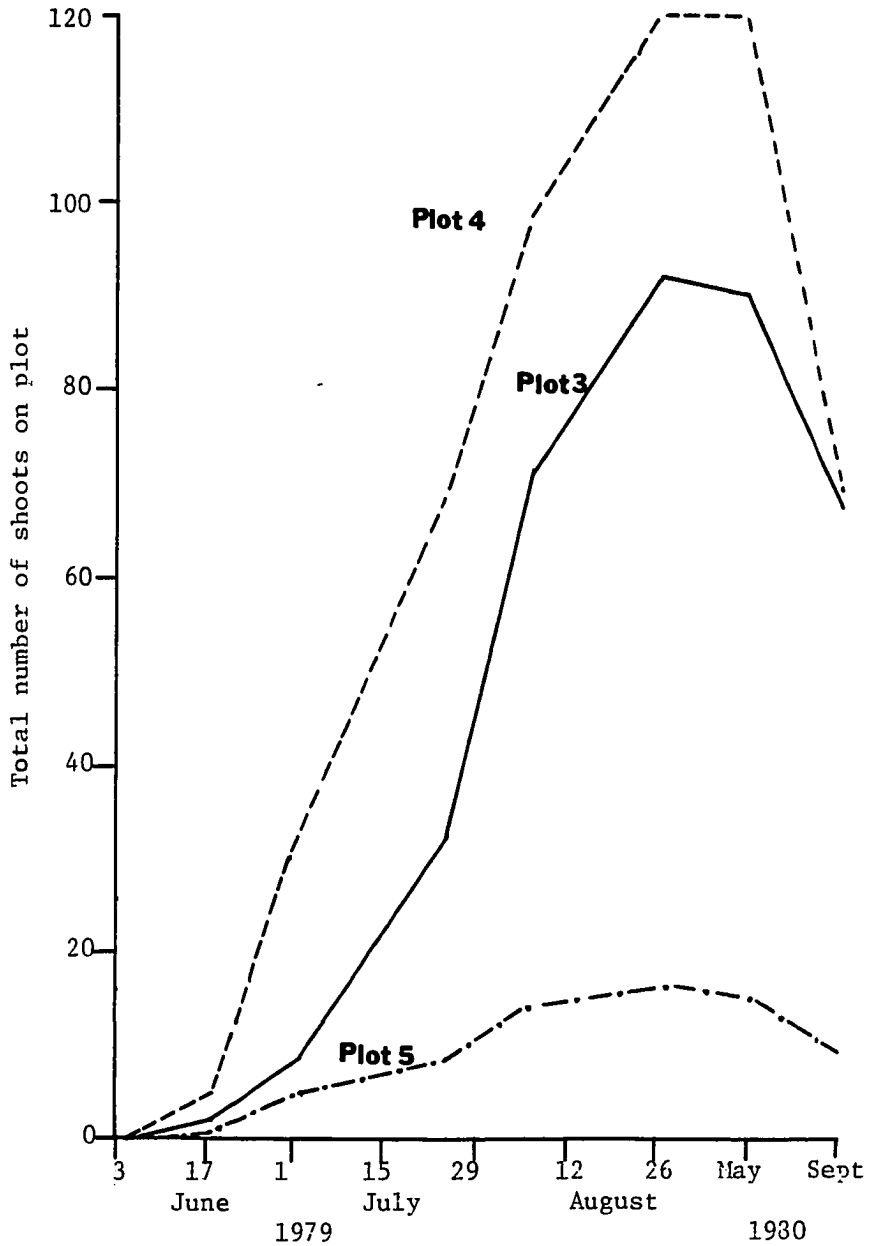


Fig. 18. Dynamics of shoot populations curves. Numbers of living stems of V. uliginosum growing on 1/2m^2 plots.

only one. Differential mortality (39% for plot 4 and 23% for plot 3) and emergence of shoots on the two plots caused a net convergence of absolute numbers in 1980.

The response of V. vitis-idaea on the transect level of resolution showed small changes in plant density from the end of 1979 to the end of the 1980 growing season. The total number of lingonberry shoots changed from 90 to 87 (Fig. 17). However, results at the plot level were more varied. Plots 4 and 6, which contained the greatest number of stems, showed a net decline in 1980 while plot 3, which had a low density in 1979, increased in 1980 (Fig. 19).

Population Structure of Clonal Plants

Population structure in plant communities can be viewed at two levels. One level is defined by the number of genets and must result from sexual reproduction. Each genet is composed of modular units (such as bud and associated leaf) of construction. The ramet of a clone is one of these modular units. The ramet, in this case, is the second level of population structure. Each ramet or genet can also be considered as a population of modular units with demographic properties (Harper 1977).

Many higher plants exhibit clonal growth which results in the formation of a population of ramets. It was the population-like structure at the ramet level which was examined in this study. Due to the clonal nature of blueberry and

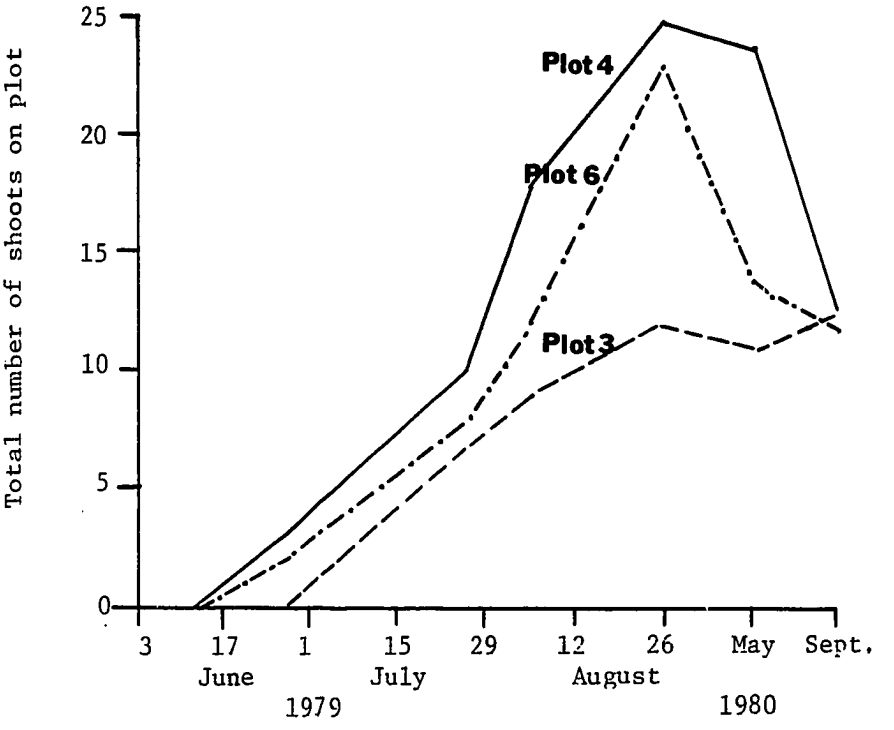


Fig. 19. Dynamics of shoot populations curves. Numbers of living stems of V. vitis-idaea growing on 1/2m^2 plots.

lingonberry, the number of genets involved in this study could not be determined and thus population dynamics and structure were described at only one level.

Under ideal conditions populations of higher plants grow exponentially by increasing the number of parts. The population growth rate declines as parts of genets or ramets compete for limited resources. When one plant competes with another, the birth and death of units of the individual plant or the number of ramets it posesses may be affected. The number of structural units and ultimately, the plant's form or "architecture" is affected. The response of a plant to stress (limited resources) can be exhibited almost entirely in the production of modular units. The changes a plant exhibits in the number of ramets present on a site two seasons after fire may be an expression of the plant's plasticity (Harper 1977).

Density Dependent and Density Independent Mortality

The changes in density and rates of mortality in this experiment may be explained in several different ways. Harper's (1977) description of the effect of neighbors upon one another as described above accounts for a portion of the shoot mortality that took place in Vaccinium between the end of the first and second growing seasons. High densities of ramets may have caused stress as ramets from the same or different genets competed for a finite amount of resources.

In general, density stress affects the birth and death rates of plant parts (Harper 1977). Plants at high densities develop stress earlier than plants at lower densities. Mortality observed in this study may be partially accounted for by the effects of density stress and the competition for resources of Vaccinium ramets upon one another (Appendix B). As shown in Fig. 18, the shoots of V. uliginosum, in plot 4, which had a higher density, experienced a death rate greater than the shoots in plot 3. The plot with low density of V. vitis-idaea shoots (Fig. 19) experienced an increase in the number of shoots (plot 3) while the number of shoots in more dense stands (plots 4 and 6) decreased.

Harper (1977) used the term "self-thinning" for density dependent mortality in plant populations. The plants most likely to die in natural thinning are the smallest and "weakest" but the mechanism for this is only dimly understood. Although no comparative measurements were made on the plots, it was observed that shoots which were late emergents experienced the highest mortality levels.

Density independent factors may also account for some of the mortality of Vaccinium stems on a site following fire. Toward the end of the 1979 growing season increased mortality was observed for shoots in some transects. Physical factors such as high surface temperatures and moisture stress may have contributed to shoot mortality.

The effects of browsing and grazing (possibly by arctic hare, Lepus arcticus) were first observed in May 1980 (Appendix B). These effects were found to occur unevenly between and within transects (Table 9). In one transect, the percent of V. uliginosum stems which were browsed ranged from 0 to 24%. In a second transect, browsing varied from 19% of the V. uliginosum stems on a plot to 71% of the stems on a plot. The effect of browsing on V. vitis-idaea was more difficult to observe since plants which were clipped of leaves easily blended into the dead moss surface. Sometimes browsing and grazing were confused with "over-winter mortality" when it was found that some dead lingonberry plants were actually browsed from below the surface of the moss.

Other factors may contribute to density independent mortality. In May 1980, extensive over-winter mortality in V. vitis-idaea was observed. Many of the leaves had a grayish-white appearance which may be attributed to snow mold or snow blight (Hepting 1971).

Vaccinium Population Dynamics and Response to Fire

In the early part of this thesis, it was demonstrated that a functional relationship existed between the residual organic mat depth and the number of shoots present on that site one and two years after fire. Although the effects of the experimental fires had the initial and greatest influence upon the postfire community, once shoots began to

Table 9. Comparison of percent browsing for two transects.

	V. uliginosum				V. vitis-idaea			
	Transect 1		Transect 2		Transect 1		Transect 2	
Plot	Number Shoots	% Browsed	Number Shoots	% Browsed	Number Shoots	% Browsed	Number Shoots	% Browsed
1	0	0	26	19	101	0	3	0
2	0	0	78	64	78	0	3	0
3	17	24	29	66	23	4	4	0
4	23	0	0	0	76	0	0	0
5	53	13	28	71	92	0	0	0
6	116	0	0	0	67	0	0	0
7	182	1	0	0	42	0	0	0
8	120	0	0	0	18	0	0	0

re-occupy the sites, other factors, such as density dependent mortality, browsing and high temperatures contributed to total shrub response. Additionally, in the years following fire Vaccinium has the ability to re-invade by underground rhizomes or by layering of above ground shoots into areas where all the organic material has been consumed. In subsequent years after fire, seedling establishment is also possible. Because of these modifying effects, the relationship between fire severity and shrub density would diminish as the effects of other factors increase. A comparison of R^2 values for regression analysis of the number of stems on a site and the severity of burn in 1979 and 1980 shows that in general, the correlation decreased slightly between one and two years after fire although the decrease was not statistically significant (Table 10).

Table 10. R^2 Values in 1979 Compared to R^2 Values in 1980

	1979	1980
Simple Linear Regression ($4M^2$)		
V. uliginosum	.52	.49
Log *V. uliginosum*	.74	.74
V. vitis-idaea	.45	.45
Log *V. vitis-idaea*	.69	.69
Simple Linear Regression ($1/2M^2$)		
V. uliginosum	.31	.29
V. vitis-idaea	.23	.22
Multiple Linear Regression ($4M^2$)		
V. uliginosum	.58	.49
Log *V. uliginosum*	.79	.74
V. vitis-idaea	.25	.25
Log *V. vitis-idaea*	.50	.49
Multiple Linear Regression ($1/2M^2$)		
V. uliginosum	.25	.12
V. vitis-idaea	.09	.11

Y = *Vaccinium* density
X_1 = Depth residual O.M.
X_2 = Preburn density of *Vaccinium*

CONCLUSIONS

The effects of the experimental fires in the black-spruce forest were to create postfire conditions which were a tesselation of unburned, scorched, partially consumed and completely consumed organic material. Vegetation response to these conditions falls into three general categories: 1) species eliminated by fire, 2) species which were not members of the prefire community but appeared after fire, and 3) species present before and after fire, but present in new proportions in burned areas.

The components of the prefire community which had the highest cover value were black spruce (Picea mariana) and the feather mosses, Hylocomium splendens and Pleurozium schreberi. After fire the greatest reduction in plant cover occurred for these species. The most prominent member of the postfire community was Epilobium angustifolium. This species was most common in sites with little or no residual organic mat.

Species present in the prefire community that returned one year after fire generally covered less area than before fire. These species were the ericaceous shrubs and Calamagrostis and were usually in sites where much of the residual organic mat remained.

A major effect of fire treatment was to alter the depth and surface condition of the organic mat. Fire severity

varied greatly over relatively small areas. Total to insignificant consumption of the organic layer could occur over an area of less than one square meter. Differences in fire severity created a continuum of survival probabilities for plant propagules. The average preburn depth of the organic mat was 25.2 cm before fire. This was reduced to 11.0 cm after fire treatment. In general, fire treatment caused an increase in the number of stems of V. uliginosum and a decrease in V. vitis-idaea. One year after fire treatment, the number of blueberry shoots increased to 145% of preburn density while lingonberry shoots decreased to 25%. Two years after fire, blueberry shoots were 110% and lingonberry shoots 23% of the preburn density.

Regression equations were used to predict a significant portion of the response of Vaccinium. The predictive value of the regression equations was greater for predicting blueberry density by using the depth of the residual organic mat and for predicting lingonberry density by using the percentage organic mat removed. The predictive value of the regression equations was greater after log transformation of the data for shoot density. A better "fit" was found for average values on the transect ($4m^2$) level of scale than for individual values for shoot density on each $\frac{1}{2}m^2$ plot. In general, the addition of a second independent variable (the preburn number of Vaccinium stems) did not improve the R^2 values of the regression equations.

Differences in certain aspects of the autecology of lingonberry and blueberry contributed to a difference in the ability of the two species to return after fire.

The dpeths of the underground plant parts were generally different for these species although some overlap occurred. V. vitis-idaea appeared to be more susceptible to fire damage due to its shallower rhizome system.

The two species also differed in size and number of above and below ground plant parts. Response to fire is possible from all dormant meristems which make up the total "bud bank" (Harper 1977). Information about clonal size and distribution indicated a species difference in the available "bud bank".

Mechanisms for clonal expansion also differed for these species. V. uliginosum clones expanded through a process similar to layering in black spruce while V. vitis-idaea spread by the elongation of fleshy rhizome tips growing below the surface (Calmes and Zasada in press). This difference suggested that these species differed in their ability to recolonize severely burned sites by vegetative means.

Species were found to differ in their ability to produce shoots. It was found that mechanically clipped "stumps" of V. uliginosum produced over twice as many shoots as "stumps" of V. vitis-idaea one growing season after clipping. The

date during the growing season that clipping was performed had a marked effect on the ability of both species to produce shoots. At the end of 1979 (the season of clipping treatment) the number of new shoots growing in the clipping treatment plots indicated that there was a constant decline in the ability to produce shoots after each successive clipping date for both species. The ability of lingonberry to produce shoots during the season of disturbance ended one week before that of blueberry.

One full year after clipping (1980) the number of shoots on plots clipped before July 17, 1979 were significantly greater than the number of shoots for plots clipped after July 17, 1979. By the end of the 1980 growing season, the number of lingonberry shoots in all plots had increased from 1979 values. At this time, blueberry plants that were treated in the early part of 1979 had decreased in number from values obtained at the end of 1979, while late season treated plots increased in density.

The response of Vaccinium to clipping treatment was greater than the overall response to fire. However, on lightly burned transects the response of both species was greater for burning than for clipping treatments, while on severely burned transects no response of either species occurred.

The rate of shoot emergence for V. vitis-idaea and V. uliginosum increased rapidly during the early part of the growing season of 1979 (the first year after fire). During this period V. uliginosum clones produced more new shoots than did clones of V. vitis-idaea. The rate of emergence of new shoots began to decrease after the first week of August. At this time, an increase in shoot mortality was observed.

More shoots died over the first winter than had died during the 1979 growing season. Heavy browsing was noted on some transects shortly after snow had melted in the beginning of the 1980 growing season. The effects of browsing were patchy; shoots in some transects were greatly damaged while the effect of browsing was imperceptible in other transects.

A net decrease in numbers occurred during the 1980 growing season. A greater net decrease occurred for the number of V. uliginosum shoots than for V. vitis-idaea. Changes in the numbers of V. vitis-idaea or V. uliginosum varied according to the particular scale at which shrub response was viewed. While overall values decreased for both species during the 1980 growing season, observations at the transect and plot scale sometimes revealed net increases in shoot numbers.

Changes in the numbers of Vaccinium may occur at the level of the individual clone, the genet, or at the level of

the individual shoot, the ramet. When plants compete for limited resources, the growth rate of the individual plant or the number of ramets it posesses may be affected.

Changes in the density of Vaccinium shoots after fire were attributed to density dependent as well as density independent factors.

A general observation made from this study was that the effects of fire severity were experienced most acutely by the postfire community in 1979. As shoots returned to the site after fire, other factors such as browsing and plant competition began to influence total shrub response. The functional relationship between shrub density and fire severity diminished slightly between 1979 and 1980 although the difference was not statistically significant.

APPLIED ECOLOGY

In Sweden and Finland, V. vitis-idaea is considered to be one of the most important wild berry crops although there have often been great fluctuations in supply (Fernqvist 1976; Lehmushovi 1979). This led to experiments in the domestication of lingonberry in these countries. It is also believed that there is potential for commercial development of V. vitis-idaea in Newfoundland and Nova Scotia and studies have been underway since the early 1970's to develop practices that promote berry production (Hall 1970).

In interior Alaska harvest of the fruit of both V. uliginosum and V. vitis-idaea is an important part of the subsistence lifestyle in many settlements (Gasbarro, et al, 1979) and a recreational activity for people living near urban areas.[2)] In a subsistence survey carried out in 1973 in the Upper Yukon-Porcupine villages, the annual harvest of berries was estimated to be about 4000 kg. About 90% of the berries harvested were V. vitis-idaea (Gasbarro, et al, 1979).

Although "Vaccinium Management" is not yet practiced in interior Alaska in a commercial sense, management of the two species is important as they are a food source for various types of wildlife. The berries of these species are known

[2)]Personal communication. (A. Jubenville, School of Agriculture and Land Resources Management, University of Alaska, Fairbanks, Alaska).

to be important for bear, martin and grouse.[3)] Results from this study may be used to define guidelines which relate to Vaccinium productivity.

VACCINIUM DENSITY AND SEVERITY OF FIRE

Equations have been developed in this study which provide a means of predicting a significant portion of Vaccinum response after fire. The variables used to determine response were:

1) A measure of fire severity - this was the depth of residual organic mat or the percentage of the organic layer burned.
2) The preburn density of Vaccinium.

Although overall there was no large difference in the results obtained from the two different measures of fire severity, use of the depth of the residual organic mat produced more predictive equations for blueberry density while use of the percentage of the organic layer consumed produced more predictive equations for lingonberry. (Table 4). The addition of the preburn density of Vaccinium did not contribute to the creation of more powerful equations of Vaccinium response than those equations using just a fire severity variable. This would indicate that in a wildfire

[3)]Personal communication. (J. Ernest, Alaska Department of Fish and Game, Fairbanks, Alaska).

situation, where managers did not have a detailed knowledge of prefire Vaccinium densities, the measurement of fire severity alone could be used to predict response in the black spruce type.

Fire treatment increased the density of new blueberry stems two years after fire, while the density of lingonberry stems was less than the preburn density. It was found that burn treatments which pruned the above ground shoots of these species without significantly altering the organic mat produced the greatest response. The investigation showed that the shallower rhizome system of V. vitis-idaea made it more susceptible to damage. Fire treatments which produce less severe conditions than the treatments used in this experiment are suggested for increased V. vitis-idaea response.

OTHER FACTORS WHICH INFLUENCE VACCINIUM RESPONSE

Clipping experiment results for one year after treatment demonstrated that the time of disturbance during the growing season may be important in determining Vaccinium response. Early season disturbance produced higher density response than late season disturbance. This was especially true for lingonberry where the late May clipping treatment was the only treatment that yielded an increased number of shoots than were originally growing on the plot.

A burn treatment which prunes aerial shoots but leaves the underground plant parts intact is superior to a clipping treatment for both species. Fire has been shown to result in both increased mineral element circulation and increased soil temperature in the black spruce type. Both of these factors act to control the productivity of vegetation (University of Alaska 1979).

Production of shoots in lingonberry occurred more slowly than in blueberry during the first growing season after fire. The majority of the blueberry response occurred the first year after fire while lingonberry response was not as great. During the second year after fire, there was a net decrease in the density of both species although blueberry experienced a greater decrease than lingonberry.

Some blueberry plants produced mature fruits two years after fire treatment, (although maximum production will occur in subsequent years). Some lingonberry plants produced fruit, but there was not time for the berries to mature before the end of the second growing season. It may take longer to establish fruit producing populations of lingonberry than blueberry.

Other factors may hamper the regeneration of these species. The most obvious additional factor was browsing (possibly by arctic hare). In one experimental transect, browsing was observed to effect 70% of the blueberry shoots.

Appendix A. Number of shoots of Vaccinium uliginosum and V. vitis-idaea on all (1/2M^2) plots preburn 1978, postburn 1979, postburn 1980 and depth of residual organic layer (cm).

Plot	Depth cm	V. uliginosum 1978	V. uliginosum 1979	V. uliginosum 1980	V. vitis-idaea 1978	V. vitis-idaea 1979	V. vitis-idaea 1980
			Unit 1				
Transect 1							
1	18.3	24	35	27	81	116	116
2	18.3	25	38	39	27	50	44
3	18.3	31	59	46	14	61	43
4	18.3	14	43	33	97	140	123
5	18.3	23	45	31	105	187	160
6	18.3	6	11	9	282	342	345
7	18.3	2	8	6	250	299	188
8	11.8	12	36	35	102	97	153
Transect 2							
1	19.3	15	146	89	141	107	119
2	25.9	42	102	60	88	56	53
3	15.3	7	89	80	53	37	32
4	22.1	4	14	13	119	67	83
5	17.9	3	15	18	150	90	56
6	12.2	20	67	49	143	21	15
7	14.3	23	105	82	75	51	49
8	13.3	15	141	142	134	39	33
Transect 3							
1	14.1	26	30	9	265	158	162
2	11.1	18	5	0	369	34	39
3	15.5	21	77	31	296	150	147
4	19.4	15	64	39	208	91	83
5	20.8	14	131	85	69	69	72
6	20.3	19	76	69	77	78	70
7	19.6	15	42	43	119	61	38
8	19.8	31	46	37	128	34	16

Appendix A. Continued

Plot	Depth cm	V. uliginosum 1978	V. uliginosum 1979	V. uliginosum 1980	V. vitis-idaea 1978	V. vitis-idaea 1979	V. vitis-idaea 1980
Transect 4							
1	15.9	69	164	123	54	36	32
2	14.7	61	226	184	89	68	50
3	18.6	82	155	116	175	75	74
4	15.1	41	176	152	68	25	25
5	20.4	71	200	164	130	102	196
6	19.5	16	37	30	14	69	98
7	16.1	53	162	143	105	55	73
8	21.8	33	93	73	140	66	51
Transect 5							
1	10.5	9	10	15	45	131	152
2	8.5	14	10	5	45	88	83
3	14.2	2	26	28	361	106	124
4	17.9	1	10	13	293	201	178
5	15.5	13	7	3	45	33	66
6	16.1	17	39	46	45	102	79
7	16.1	25	38	34	141	189	206
8	16.1	16	24	23	169	226	175
Transect 6							
1	10.5	0	0	0	230	111	142
2	15.2	0	0	0	92	61	51
3	15.7	0	0	0	28	20	26
4	14.1	3	2	0	182	184	144
5	13.5	3	3	3	180	270	169
6	17.3	14	24	26	261	156	103
7	22.1	23	70	29	121	52	46
8	17.9	3	16	12	92	45	31

Appendix A. Continued

Plot	Depth cm	V. uliginosum 1978	V. uliginosum 1979	V. uliginosum 1980	V. vitis-idaea 1978	V. vitis-idaea 1979	V. vitis-idaea 1980
			Unit 2				
Transect 1							
1	2.3	0	0	0	58	0	0
2	3.7	0	0	0	52	0	0
3	4.5	0	0	0	158	0	0
4	4.3	0	0	0	71	0	0
5	4.1	17	0	0	117	0	0
6	4.2	46	0	0	115	0	0
7	4.2	51	0	0	101	0	0
8	5.1	21	0	0	62	0	0
Transect 2							
1	6.1	3	0	0	44	0	0
2	3.3	3	0	0	82	0	0
3	3.7	19	0	0	146	0	0
4	2.6	38	0	0	37	0	0
5	2.8	27	0	0	30	0	0
6	3.6	14	0	0	80	0	0
7	5.1	21	6	5	82	0	0
8	4.4	1	0	0	110	0	0
Transect 3							
1	4.8	0	0	0	89	0	0
2	5.6	1	0	0	153	0	0
3	3.1	2	0	0	74	0	0
4	3.3	1	0	0	55	0	0
5	4.0	0	0	1	113	0	0
6	8.6	0	0	0	68	15	10
7	5.7	0	0	0	94	3	0
8	6.5	1	0	0	105	0	0

Appendix A. Continued

Plot	Depth cm	V. uliginosum 1978	V. uliginosum 1979	V. uliginosum 1980	V. vitis-idaea 1978	V. vitis-idaea 1979	V. vitis-idaea 1980
Transect 4							
1	3.4	10	0	0	67	0	0
2	4.9	5	0	0	147	0	0
3	3.7	4	0	0	184	0	0
4	2.5	4	0	0	137	0	0
5	6.1	22	7	0	75	0	0
6	17.0	15	8	15	79	6	1
7	20.9	37	55	36	95	10	5
8	24.4	24	1	10	64	4	0
Transect 5							
1	7.8	0	0	0	5	0	0
2	17.8	0	0	0	103	1	1
3	14.6	0	0	0	85	12	12
4	12.3	0	0	0	91	7	2
5	5.8	0	0	0	140	0	0
6	7.0	0	0	0	86	0	0
7	9.0	5	0	0	162	0	0
8	12.8	1	5	0	143	1	0

Appendix A. Continued

Plot	Depth cm	V. uliginosum 1978	V. uliginosum 1979	V. uliginosum 1980	V. vitis-idaea 1978	V. vitis-idaea 1979	V. vitis-idaea 1980
			Unit 3				
Transect 1							
1	14.5	46	48	3	29	3	0
2	23.2	116	130	27	49	3	1
3	20.3	63	39	19	62	4	7
4	8.7	3	0	0	101	0	0
5	9.1	9	28	14	28	0	0
6	15.6	43	0	0	15	0	0
7	5.9	3	0	0	6	0	0
8	6.4	8	0	0	38	0	0
Transect 2							
1	7.3	24	0	0	93	0	0
2	3.4	52	0	0	55	0	0
3	3.5	30	0	0	55	0	0
4	2.7	21	0	0	83	0	0
5	3.9	3	0	0	78	0	0
6	3.3	3	0	0	131	0	0
7	3.1	0	0	0	90	3	1
8	4.7	0	1	0	81	0	0
Transect 3							
1	4.7	0	0	0	37	0	0
2	4.4	0	0	0	25	0	0
3	10.0	0	0	0	20	0	0
4	5.3	12	0	0	67	0	0
5	5.2	30	0	0	76	0	0
6	3.2	19	0	0	121	0	0
7	4.1	99	0	0	92	0	0
8	4.1	45	0	0	63	0	0

Appendix A. Continued

Plot	Depth cm	V. uliginosum 1978	V. uliginosum 1979	V. uliginosum 1980	V. vitis-idaea 1978	V. vitis-idaea 1979	V. vitis-idaea 1980
Transect 4							
1	3.9	30	0	0	24	0	0
2	3.4	36	0	8	46	0	0
3	5.3	45	13	3	48	0	0
4	4.9	60	0	0	122	0	0
5	4.5	0	0	0	120	0	0
6	5.4	2	0	0	76	0	0
7	4.5	4	6	8	95	0	0
8	9.8	0	2	3	54	0	0
Transect 5							
1	(5.0)	0	0	0	48	0	0
2	5.0	0	0	0	37	0	0
3	5.0	0	0	0	41	0	0
4	5.0	0	0	0	95	0	0
5	5.0	0	0	0	39	0	0
6	5.0	0	0	0	39	0	0
7	5.0	0	0	0	98	0	0
8	5.0	0	0	0	45	0	0

Appendix A. Continued

Plot	Depth cm	V. uliginosum 1978	V. uliginosum 1979	V. uliginosum 1980	V. vitis-idaea 1978	V. vitis-idaea 1979	V. vitis-idaea 1980
			Unit 5				
Transect 1							
1	19.6	1	0	0	297	101	56
2	19.7	7	0	1	145	78	34
3	19.7	20	20	8	121	25	16
4	23.3	2	24	18	180	75	43
5	24.6	15	54	52	110	92	115
6	28.4	28	119	96	66	67	70
7	26.2	24	182	140	34	42	46
8	21.4	27	120	99	37	18	20
Transect 2							
1	11.7	1	4	4	52	20	31
2	14.6	15	13	16	42	4	9
3	17.1	26	93	72	49	12	13
4	22.1	21	120	73	59	25	13
5	20.6	17	17	11	63	6	9
6	20.6	7	0	0	107	23	12
7	8.5	3	0	0	98	0	0
8	1.6	7	0	0	74	0	0
Transect 3							
1	8.1	0	0	0	131	0	0
2	3.1	0	0	0	13	0	0
3	5.6	0	0	0	9	0	0
4	6.3	0	0	0	126	0	0
5	11.4	8	0	0	112	0	0
6	13.4	6	8	11	92	3	1
7	18.9	8	10	10	98	6	9
8	2.2	3	0	0	62	0	0

Appendix A. Continued

Plot	Depth cm	V. uliginosum 1978	V. uliginosum 1979	V. uliginosum 1980	V. vitis-idaea 1978	V. vitis-idaea 1979	V. vitis-idaea 1980
Transect 4							
1	2.7	0	0	0	149	0	0
2	1.1	0	0	0	164	0	0
3	4.5	0	0	0	114	0	0
4	5.4	0	0	0	246	0	0
5	8.1	0	0	0	169	0	0
6	5.3	0	0	0	123	0	0
7	11.8	0	1	1	41	2	0
8	10.8	0	0	0	205	5	0
Transect 5							
1	5.7	0	0	0	68	0	0
2	6.8	0	0	0	39	0	0
3	10.3	0	0	0	21	0	0
4	10.5	1	0	0	14	0	0
5	15.1	2	0	0	36	4	0
6	14.7	5	5	6	47	0	0
7	16.3	2	37	33	40	28	5
8	16.8	9	0	0	60	8	5

Appendix A. Continued

Plot	Depth cm	V. uliginosum 1978	V. uliginosum 1979	V. uliginosum 1980	V. vitis-idaea 1978	V. vitis-idaea 1979	V. vitis-idaea 1980
			Unit 6				
Transect 1							
1	Missing	8	0	0	133	0	0
2		15	0	0	95	0	0
3		1	0	0	128	0	0
4		1	0	0	77	0	0
5		2	0	0	205	0	0
6		3	0	0	183	0	0
7		0	0	0	206	0	0
8		7	0	0	79	0	0
Transect 2							
1	5.6	1	0	0	151	0	0
2	9.8	3	0	0	116	0	0
3	9.7	11	3	15	76	1	0
4	16.4	0	3	5	69	1	0
5	10.6	0	0	0	50	0	0
6	5.3	0	0	0	53	0	0
7	9.0	0	0	0	128	0	0
8	10.3	0	0	0	116	0	0
Transect 3							
1	3.9	0	0	0	143	0	0
2	4.0	0	0	0	160	0	0
3	9.0	0	0	0	90	0	0
4	8.7	6	0	0	51	0	0
5	9.5	20	0	0	88	0	0
6	8.3	0	0	0	100	0	0
7	15.7	1	1	4	87	11	8
8	11.4	5	0	0	94	1	0

Appendix A. Continued

Plot	Depth cm	V. uliginosum 1978	V. uliginosum 1979	V. uliginosum 1980	V. vitis-idaea 1978	V. vitis-idaea 1979	V. vitis-idaea 1980
Transect 4							
1	4.0	3	0	0	117	0	0
2	7.6	20	0	0	121	0	0
3	13.3	16	28	8	114	6	0
4	10.1	32	12	2	152	0	0
5	8.5	16	0	0	130	0	0
6	7.6	22	0	0	90	0	0
7	7.3	24	0	0	74	0	0
8	7.7	0	0	0	92	0	0
Transect 5							
1	16.7	0	0	0	102	0	0
2	16.1	0	0	0	149	0	0
3	8.0	0	0	0	276	0	0
4	5.8	0	0	0	151	0	0
5	10.7	0	0	0	204	0	0
6	11.2	0	0	0	243	0	0
7	12.3	1	0	0	162	0	0
8	11.3	5	0	0	147	0	0

Appendix A. Continued

Plot	Depth cm	V. uliginosum 1978	V. uliginosum 1979	V. uliginosum 1980	V. vitis-idaea 1978	V. vitis-idaea 1979	V. vitis-idaea 1980
			Unit 7				
Transect 1							
1	13.5	3	0	0	180	19	15
2	19.4	0	0	0	137	39	19
3	12.7	0	0	0	238	17	11
4	5.9	0	0	0	126	22	0
5	8.0	0	0	0	54	3	11
6	7.1	0	0	0	52	0	0
7	5.4	0	0	0	80	0	0
8	7.9	0	0	0	72	0	0
Transect 2							
1	10.9	16	0	0	146	0	0
2	10.0	17	0	0	68	0	0
3	11.3	13	74	60	98	5	5
4	6.9	13	0	0	28	0	0
5	10.5	29	15	7	43	9	4
6	12.8	34	31	19	123	19	17
7	7.0	14	0	0	135	0	0
8	10.3	35	0	0	263	0	0
Transect 3							
1	26.5	54	113	100	109	42	48
2	28.5	49	46	43	47	9	6
3	17.3	40	110	68	84	9	8
4	10.3	22	10	0	129	0	0
5	14.8	22	15	12	110	5	2
6	5.8	28	0	0	115	0	0
7	6.0	23	0	0	180	0	0
8	8.6	21	10	10	100	7	5

Appendix A. Continued

Plot	Depth cm	V. uliginosum 1978	V. uliginosum 1979	V. uliginosum 1980	V. vitis-idaea 1978	V. vitis-idaea 1979	V. vitis-idaea 1980
Transect 4							
1	9.7	0	0	0	10	1	1
2	13.3	8	7	1	40	7	4
3	9.7	5	0	5	77	5	7
4	5.0	17	0	0	82	0	0
5	8.4	1	0	0	65	0	0
6	8.7	0	0	0	44	0	0
7	10.6	3	0	0	168	0	0
8	15.6	28	21	17	44	3	1
Transect 5							
1	12.7	0	0	0	37	6	10
2	17.0	0	0	0	128	96	49
3	8.4	6	0	0	96	12	37
4	6.9	1	1	0	75	0	0
5	5.3	8	1	0	10	0	0
6	4.0	3	0	0	13	0	0
7	4.0	0	0	0	5	0	0
8	8.7	0	0	0	4	0	0

Appendix B. Vaccinium vitis-idaea and V. uliginosum shoots on all ($1/2M^2$) plots.

Date	Plot	Transect 1 u	Transect 1 v	Transect 2 u	Transect 2 v	Transect 3 u	Transect 3 v	Transect 4 u	Transect 4 v	Transect 5 u	Transect 5 v	Transect 6 u	Transect 6 v
						Unit 1							
						Totals							
5 Jun 79	1	15	81	7	50	0	2	6	2	3	80	0	76
	2	35	45	0	0	0	1	7	0	2	42	0	54
	3	44	50	4	0	0	0	4	1	0	57	0	23
	4	37	130	0	2	2	2	6	0	1	109	2	180
	5	38	172	3	2	3	2	5	3	7	23	3	222
	6	10	305	0	0	8	0	0	1	17	45	0	126
	7	1	217	15	2	0	0	9	0	25	141	0	20
	8	0	0	10	0	1	0	0	0	16	169	0	18
						New Shoots							
18 Jun 79	1	0	8	8	8	0	3	10	3	1	6	0	11
	2	0	5	0	0	0	1	10	0	0	0	0	0
	3	0	0	5	0	0	1	4	1	0	0	0	0
	4	0	0	0	3	3	2	10	0	2	3	0	2
	5	0	0	4	3	5	3	8	5	0	3	unburned	
	6	0	0	1	0	11	0	0	1	0	0	0	4
	7	5	6	19	3	1	0	14	0	0	0	0	5
	8	1	3	12	1	1	0	0	0	0	0	0	0
						New Shoots							
27 Jun 79	1	0	6	19	13	0	9	21	5	1	15	0	2
	2	0	2	2	4	0	0	35	4	1	3	0	0
	3	0	0	8	5	0	9	22	3	6	0	0	0
	4	0	0	3	8	14	7	23	1	0	3	0	0
	5	0	0	11	8	18	6	17	10	1	4	0	0
	6	0	0	2	3	9	14	2	9	0	0	2	5
	7	0	10	16	7	8	6	12	1	0	0	1	0
	8	9	4	15	5	4	1	0	2	0	0	0	4

Appendix B. Continued.

Date	Plot	Transect 1 u	Transect 1 v	Transect 2 u	Transect 2 v	Transect 3 u	Transect 3 v	Transect 4 u	Transect 4 v	Transect 5 u	Transect 5 v	Transect 6 u	Transect 6 v
					New Shoots								
24 Jul 79	1	11	42	22	31	8	39	44	12	0	2	0	18
	2	2	14	21	4	1	7	66	11	0	18	0	0
	3	0	0	26	13	26	39	61	13	7	14	0	0
	4	0	0	6	25	16	18	52	5	2	18	0	0
	5	0	0	5	26	45	21	101	47	3	3	0	0
	6	0	0	33	5	20	10	21	13	0	0	16	0
	7	0	0	20	15	21	11	46	12	0	0	8	4
	8	15	16	62	14	21	12	32	6	0	0	7	0
					New Shoots								
7 Aug 79	1	3	32	8	3	7	62	28	12	5	28	0	0
	2	0	0	36	31	0	17	27	23	5	25	0	0
	3	0	0	41	12	30	59	28	35	11	35	0	0
	4	0	0	2	20	10	49	23	18	7	68	0	0
	5	0	0	0	27	36	17	20	18	1	10	0	0
	6	0	0	14	3	11	30	14	35	0	0	3	0
	7	0	17	31	15	10	25	64	26	0	0	24	16
	8	3	24	28	8	22	16	39	29	0	0	0	13
					Totals								
22 Aug 79	1	35	116	146	107	30	158	164	36	10	131	0	111
	2	38	50	102	56	5	34	226	68	10	88	0	61
	3	59	61	89	37	77	150	155	75	26	106	0	20
	4	43	140	14	67	64	91	176	25	10	201	2	184
	5	45	187	15	90	131	69	200	102	7	33	3	270
	6	11	342	67	21	76	78	37	69	39	102	24	156
	7	8	299	105	51	42	61	162	55	38	189	70	52
	8	36	97	141	39	46	34	93	66	24	226	16	45

Appendix B. Continued.

Date	Plot	Transect 1 u	Transect 1 v	Transect 2 u	Transect 2 v	Transect 3 u	Transect 3 v	Transect 4 u	Transect 4 v	Transect 5 u	Transect 5 v	Transect 6 u	Transect 6 v
						Shoot Mortality							
May 80	1	1	15	0	0	5	8	5	5	0	7	0	3
	2	0	0	9	8	1	4	15	6	0	4	0	0
	3	0	0	2	4	9	8	3	8	0	4	0	0
	4	0	0	0	2	0	10	3	2	1	19	0	0
	5	0	0	2	17	7	3	10	3	1	5	0	0
	6	0	0	1	2	5	6	7	5	0	0	0	1
	7	0	0	2	2	6	7	11	8	0	0	2	5
	8	0	0	3	5	7	20	12	9	0	0	0	7
						Totals							
29 Aug 80	1	27	116	89	119	9	162	123	32	15	152	0	142
	2	39	44	60	53	0	39	184	50	5	83	0	51
	3	46	43	80	32	31	147	116	74	28	124	0	26
	4	33	123	13	83	39	83	152	25	13	178	0	144
	5	31	160	18	56	85	72	164	196	3	66	3	169
	6	9	345	49	15	69	70	30	98	46	79	26	103
	7	6	188	82	49	43	38	143	73	34	175	29	46
	8	35	153	142	33	37	16	73	51	23	206	12	31

Appendix B. Continued

Date	Plot	Transect 1 u	Transect 1 v	Transect 2 u	Transect 2 v	Transect 3 u	Transect 3 v	Transect 4 u	Transect 4 v	Transect 5 u	Transect 5 v
					Unit 2						
7 Jun 80	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0
19 Jun 80	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	2	2	0	0	0
	7	0	0	0	0	0	0	3	2	0	0
	8	0	0	0	0	0	0	3	0	0	0
27 Jun	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	3
	4	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	1	0	0	0	0
	6	0	0	0	0	0	0	5	0	0	0
	7	0	0	0	0	0	0	17	0	0	0
	8	0	0	0	0	0	0	1	0	0	0
26 Jul	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	2
	3	0	0	0	0	0	0	0	0	0	5
	4	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	4	0	0	0
	6	0	0	0	0	0	1	2	1	0	0
	7	0	0	3	0	0	2	15	1	0	0
	8	0	0	0	0	0	0	6	0	0	1

Appendix B. Continued

Date	Plot	Transect 1 u	Transect 1 v	Transect 2 u	Transect 2 v	Transect 3 u	Transect 3 v	Transect 4 u	Transect 4 v	Transect 5 u	Transect 5 v
8 Aug	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	2	0
	3	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	3
	6	0	0	0	0	0	0	0	1	0	1
	7	0	0	2	0	0	7	12	4	0	0
	8	0	0	0	0	0	0	0	1	0	0
					Totals						
29 Aug	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	1
	3	0	0	0	0	0	0	0	0	0	12
	4	0	0	0	0	0	0	0	0	0	7
	5	0	0	0	0	0	0	7	0	0	0
	6	0	0	0	0	0	15	8	6	0	0
	7	0	0	6	0	0	3	55	10	0	0
	8	0	0	0	0	0	0	1	4	5	1
					Shoot Mortality						
May 80	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	1
	3	0	0	0	0	0	0	0	0	0	2
	4	0	0	0	0	0	0	0	0	0	5
	5	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	6	0	0	0	0
	7	0	0	0	0	0	0	6	2	0	0
	8	0	0	0	0	0	0	4	4	0	1

Appendix B. Continued

Date	Plot	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5	
		u	v	u	v	u	v	u	v	u	v
						Totals					
7 Sep	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	1
	3	0	0	0	0	0	0	0	0	0	12
	4	0	0	0	0	0	0	0	0	0	2
	5	0	0	0	0	1	0	0	0	0	0
	6	0	0	0	0	0	10	15	1	0	0
	7	0	0	5	0	0	0	36	5	0	0
	8	0	0	0	0	0	0	10	0	0	0

Appendix B. Continued

Date	Plot	Transect 1 u	Transect 1 v	Transect 2 u	Transect 2 v	Transect 3 u	Transect 3 v	Transect 4 u	Transect 4 v	Transect 5 u	Transect 5 v
					Unit 3						
7 Jun	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0
19 Jun	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	2	0	0	0
	4	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	1	0	0	0
27 Jun	1	1	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0
	3	5	0	3	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0
	7	0	0	2	0	0	0	0	0	0	0
	8	0	0	1	0	0	0	0	0	0	0
27 Jul	1	12	2	0	0	0	0	0	0	0	0
	2	43	0	0	0	0	0	0	0	0	0
	3	32	2	0	0	0	0	5	0	0	0
	4	0	0	0	0	0	0	0	0	0	0
	5	19	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	3	0	0	3	0	0	0
	8	0	0	1	0	0	0	0	0	0	0

Appendix B. Continued

Date	Plot	Transect 1 u	Transect 1 v	Transect 2 u	Transect 2 v	Transect 3 u	Transect 3 v	Transect 4 u	Transect 4 v	Transect 5 u	Transect 5 v
7 Aug	1	20	0	0	0	0	0	0	0	0	0
	2	42	3	0	0	0	0	6	0	0	0
	3	3	1	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0
	5	15	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	1	0	0	0
	8	0	0	0	0	0	0	0	0	0	0
					Totals						
27 Aug	1	48	3	0	0	0	0	0	0	0	0
	2	130	3	0	0	0	0	13	0	0	0
	3	39	4	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0
	5	28	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	6	0	0	0
	8	0	0	1	0	0	0	2	0	0	0
					Shoot Mortality						
May	1	22	0	0	0	0	0	0	0	0	0
	2	52	2	0	0	0	0	7	0	0	0
	3	10	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	2	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0

Appendix B. Continued

Date	Plot	Transect 1 u	Transect 1 v	Transect 2 u	Transect 2 v	Transect 3 u	Transect 3 v	Transect 4 u	Transect 4 v	Transect 5 u	Transect 5 v
						Totals					
7 Sep	1	3	0	0	0	0	0	0	0	0	0
	2	27	1	0	0	0	0	8	0	0	0
	3	19	7	0	0	0	0	3	0	0	0
	4	0	0	0	0	0	0	0	0	0	0
	5	14	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	8	0	0	0
	8	0	0	0	0	0	0	3	0	0	0

Appendix B. Continued

Date	Plot	Transect 1 u	Transect 1 v	Transect 2 u	Transect 2 v	Transect 3 u	Transect 3 v	Transect 4 u	Transect 4 v	Transect 5 u	Transect 5 v
					Unit 5						
6 Jun	1	10	0	0	0	0	0	0	0	0	0
	2	8	0	2	0	0	0	0	0	0	0
	3	18	2	0	0	0	0	0	0	0	0
	4	1	0	0	0	0	0	0	0	0	0
	5	9	2	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	1	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0
					New Shoots						
18 Jun	1	0	0	0	0	0	0	0	0	0	0
	2	1	2	0	0	0	0	0	0	0	0
	3	5	0	1	0	0	0	0	0	0	0
	4	0	0	5	0	0	0	0	0	0	0
	5	4	8	2	0	0	0	0	0	0	0
	6	21	5	0	0	0	0	0	0	0	0
	7	24	0	0	0	1	0	0	0	0	0
	8	12	1	0	0	0	0	0	0	1	0
27 Jun	1	0	14	2	7	0	0	0	0	0	0
	2	0	6	0	0	0	0	0	0	0	0
	3	0	1	7	0	0	0	0	0	0	0
	4	0	8	23	2	0	0	0	0	0	0
	5	8	16	2	2	0	0	0	0	0	0
	6	23	6	0	3	0	0	0	0	3	0
	7	37	2	0	0	3	4	0	3	10	3
	8	17	3	0	0	0	0	0	0	0	4

Appendix B. Continued

Date	Plot	Transect 1 u	Transect 1 v	Transect 2 u	Transect 2 v	Transect 3 u	Transect 3 v	Transect 4 u	Transect 4 v	Transect 5 u	Transect 5 v
24 Jul	1	0	32	0	6	0	0	0	0	0	0
	2	0	21	9	1	0	0	0	0	0	0
	3	1	11	26	7	0	0	0	0	0	0
	4	8	24	44	8	0	0	0	0	0	0
	5	22	45	4	6	0	0	0	0	0	0
	6	49	24	0	5	7	0	0	0	2	0
	7	41	20	0	0	5	3	0	2	14	5
	8	57	5	0	0	0	0	0	2	0	2
7 Aug	1	0	32	0	13	0	0	0	0	0	0
	2	1	24	7	1	0	0	0	0	0	0
	3	8	14	41	2	0	0	0	0	0	0
	4	10	27	27	8	0	0	0	0	0	0
	5	9	21	7	4	0	0	0	0	0	0
	6	18	12	0	6	0	2	0	0	0	0
	7	25	19	0	0	2	2	2	0	13	9
	8	25	6	0	0	0	0	2	0	0	3
					Totals						
27 Aug	1	0	101	4	20	0	0	0	0	0	0
	2	0	78	13	4	0	0	0	0	0	0
	3	20	25	93	12	0	0	0	0	0	0
	4	24	75	120	25	0	0	0	0	0	0
	5	54	92	17	6	0	0	0	0	0	4
	6	119	67	0	23	8	3	0	0	5	0
	7	182	42	0	0	10	6	1	2	37	28
	8	120	18	0	0	0	0	0	5	0	8

Appendix B. Continued

Date	Plot	Transect 1 u	Transect 1 v	Transect 2 u	Transect 2 v	Transect 3 u	Transect 3 v	Transect 4 u	Transect 4 v	Transect 5 u	Transect 5 v
					Shoot Mortality						
May 80	1	0	8	0	3	0	0	0	0	0	0
	2	2	9	10	0	0	0	0	0	0	0
	3	3	2	4	1	0	0	0	0	0	0
	4	1	2	0	1	0	0	0	0	0	0
	5	1	3	1	0	0	0	0	0	0	0
	6	0	1	0	4	0	0	0	0	0	0
	7	0	1	0	0	2	0	0	0	0	0
	8	1	0	0	0	0	0	0	0	0	0
					Totals						
Sep 80	1	99	20	4	31	0	0	0	0	0	0
	2	140	46	16	9	0	0	0	0	0	0
	3	96	70	72	13	0	0	0	0	0	0
	4	52	115	73	13	0	0	0	0	0	0
	5	18	43	11	9	0	0	0	0	0	0
	6	8	16	0	12	0	0	0	0	6	0
	7	1	34	0	0	11	1	1	0	23	5
	8	0	56	0	0	10	9	0	0	0	5

Appendix B. Continued

Date	Plot	Transect 1 u	Transect 1 v	Transect 2 u	Transect 2 v	Transect 3 u	Transect 3 v	Transect 4 u	Transect 4 v	Transect 5 u	Transect 5 v
7 Jun	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0
18 Jun	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0
27 Jun	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0
27 Jul	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	10	0	0	0
	4	0	0	1	0	0	0	7	0	0	0
	5	0	0	1	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	1	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0

Appendix B. Continued

Date	Plot	Transect 1 u	Transect 1 v	Transect 2 u	Transect 2 v	Transect 3 u	Transect 3 v	Transect 4 u	Transect 4 v	Transect 5 u	Transect 5 v
7 Aug	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0
	3	0	0	3	1	0	0	0	0	0	0
	4	0	0	3	1	0	0	0	0	0	0
	5	0	0	0	0	0	0	4	0	0	0
	6	0	0	0	0	0	0	5	0	0	0
	7	0	0	0	0	0	10	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0
27 Aug	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0
	3	0	0	3	1	0	0	28	6	0	0
	4	0	0	3	1	0	0	12	0	0	0
	5	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	1	11	0	0	0	0
	8	0	0	0	0	0	1	0	0	0	0
					Shoot Mortality						
	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0
	3	0	0	1	0	0	0	12	1	0	0
	4	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	1	1	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0

Appendix B. Continued

Date	Plot	Transect 1 u	Transect 1 v	Transect 2 u	Transect 2 v	Transect 3 u	Transect 3 v	Transect 4 u	Transect 4 v	Transect 5 u	Transect 5 v
						Totals					
Sep 80	1	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0
	3	0	0	15	0	0	0	8	0	0	0
	4	0	0	5	0	0	0	2	0	0	0
	5	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	4	8	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0

Appendix B. Continued

Date	Plot	Transect 1 u	Transect 1 v	Transect 2 u	Transect 2 v	Transect 3 u	Transect 3 v	Transect 4 u	Transect 4 v	Transect 5 u	Transect 5 v
					Unit 7						
					Totals						
6 Jun	1	0	1	0	0	8	1	0	0	0	0
	2	0	1	0	0	0	0	1	0	1	10
	3	0	0	0	0	0	0	2	0	0	0
	4	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	1	0	0	0
18 Jun	1	0	0	0	0	14	3	0	0	0	0
	2	0	3	0	0	3	0	0	0	0	6
	3	0	0	0	0	2	0	3	1	0	0
	4	0	0	0	0	0	0	0	0	0	0
	5	0	2	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	6	0	0	0
27 Jun	1	0	5	0	0	9	4	0	0	0	5
	2	0	7	5	0	7	0	3	0	0	4
	3	0	0	4	0	3	0	0	0	0	4
	4	0	1	0	0	4	0	0	0	0	0
	5	2	2	3	0	0	0	0	0	0	0
	6	1	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	6	0	0	0
27 Jul	1	0	7	0	0	46	22	0	0	0	5
	2	0	24	21	0	26	4	4	7	0	45
	3	0	13	24	0	29	0	0	2	1	10
	4	0	0	0	0	47	0	16	0	0	0
	5	0	14	5	0	3	1	0	0	0	0
	6	0	0	9	2	13	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0

Appendix B. Continued

Date	Plot	Transect 1 u	Transect 1 v	Transect 2 u	Transect 2 v	Transect 3 u	Transect 3 v	Transect 4 u	Transect 4 v	Transect 5 u	Transect 5 v
8 Aug	1	0	6	0	0	14	3	0	1	0	3
	2	0	11	0	0	5	4	0	4	0	22
	3	0	6	5	1	42	3	0	4	1	11
	4	0	0	0	0	5	0	0	0	3	0
	5	0	3	3	4	2	3	0	0	0	0
	6	0	3	16	5	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	4	4	6	3	0	0
					Totals						
27 Aug	1	0	19	0	0	113	42	0	1	0	6
	2	0	39	0	0	46	9	7	7	10	96
	3	0	17	74	5	110	9	0	5	10	12
	4	0	22	0	0	10	0	0	0	1	0
	5	0	3	15	9	15	5	0	0	1	0
	6	0	0	31	19	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	10	7	21	3	0	0
					Shoot Mortality						
May 80	1	0	7	0	0	0	0	0	0	0	0
	2	0	20	0	0	0	0	0	0	0	0
	3	0	2	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0
	5	0	8	0	0	0	0	0	0	0	0
	6	0	2	13	7	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0

Appendix B. Continued

Date	Plot	Transect 1 u	Transect 1 v	Transect 2 u	Transect 2 v	Transect 3 u	Transect 3 v	Transect 4 u	Transect 4 v	Transect 5 u	Transect 5 v
						Totals					
11 Sep 80	1	0	15	0	0	100	48	0	1	0	10
	2	0	19	0	0	43	6	1	4	0	49
	3	0	11	60	5	68	8	5	7	0	37
	4	0	0	0	0	0	0	0	0	0	0
	5	0	11	7	4	12	2	0	0	0	0
	6	0	0	19	17	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	10	5	17	1	0	0

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